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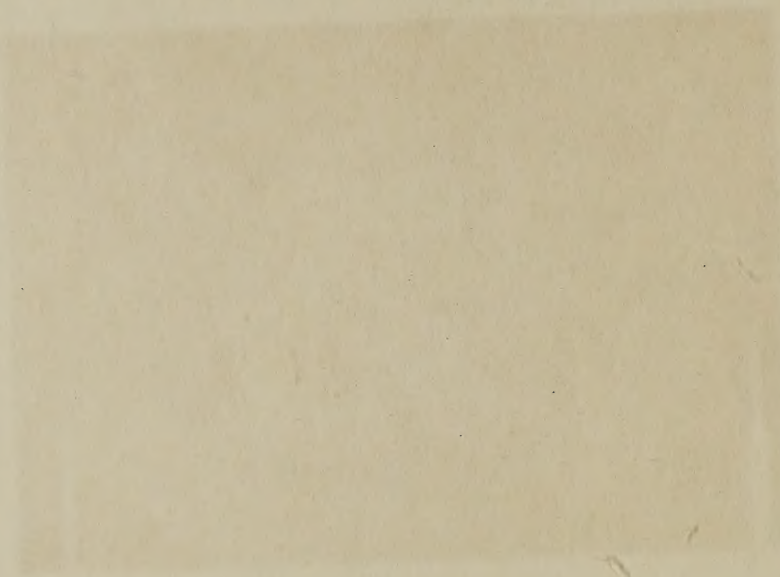

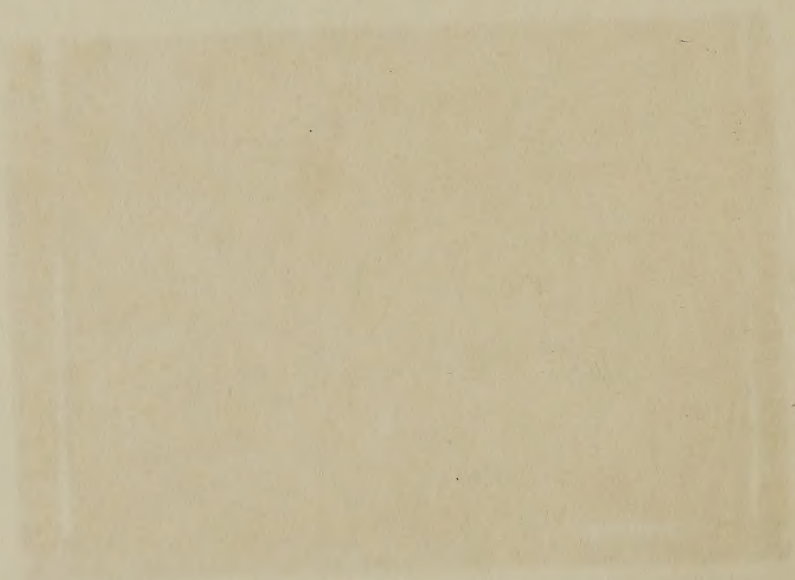

B & T REFERENCE

STREET RAILWAYS;

THEIR

CONSTRUCTION, OPERATION AND MAINTENANCE.

(TRAMS)

A Practical Handbook for Street Railway Men.

FORT WAYNE AND ALLEN COUNTY, IND.
PUBLIC LIBRARY

BY

C. B. FAIRCHILD,

EDITOR OF THE STREET RAILWAY JOURNAL.

NEW YORK:
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PREFACE.

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The following pages represent an earnest effort to present in convenient form many of the facts bearing on that wonderful industry which has for its object the transportation of urban and suburban dwellers quickly, cheaply and comfortably to and from their homes. The work is not based on theory, but is the outcome of actual practice, and is designed to be helpful to street railway men and engineers in every department, whether mechanical or financial, and also to be of interest to the student of economic subjects, who may wish to inform himself regarding this particular industry, for it is the first and only work that covers the entire field. The book is not to be read through and laid aside; but as its name implies, it is designed as a handbook for those building or operating either electric, cable, horse or elevated lines, to which reference can be had as occasion demands. To all who wish to study electric traction, the first chapter presents the essential features of the service, or at least gives such aid as one needs to form an acquaintance with the subject, and the subsequent chapters will be found reasonably complete regarding the special subjects treated.

The writer has endeavored to treat each topic in a simple manner, having in mind the needs of new men who may engage in the service, and who must necessarily learn the business by first studying the alphabet in about the same manner as the veterans when they learned the rudiments of the business. For this reason, especially in the first chapter, many old and familiar illustrations have been employed; but these, it is hoped, will not give offense to the veterans and provoke criticism, but will rather remind them pleasantly of the steps by which they attained to their present eminence.

The author has avoided affixing a positive endorsement of certain devices and methods, thinking it better to furnish the inquirer with the means of doing so for himself by showing the origin of the design, how it is constructed and how it has behaved in actual service. In like manner, the different chapters have not been written with a view of advocating any particular system of traction, but rather with a view of leading to free inquiry, extended inspection and careful selection as to the surest course for determining the system best suited to particular conditions.

Besides being directly helpful to men actually engaged in this business, it is hoped that the work will be of service in elevating this particular industry, and the men engaged in it, to a higher rank in public estimation. Any one who scans these pages must be convinced that to become a successful manager or engineer in street railway affairs one must be possessed of talents of no mean order, and be thoroughly informed on a multitude of mechanical details ranging from the qualities of a horse shoe nail up to the particular merits of the two machines which represent the best inventive thought of the age, the steam engine and the electric generator. Not only must he have a wide range of mechanical knowledge, but he must also be well informed upon the scientific, social, legal, financial and economic questions of the day.

The work makes little pretense to literary or typographical merit, and the author is fully aware that if he could revise the work it would be greatly improved. This is not said, however, to disarm criticism, for criticism is invited, particularly as to matter, omissions, etc., for should it be thought desirable to issue a second edition it could, doubtless, be improved along the lines suggested by helpful criticism.

The author takes this opportunity to express his grateful thanks to those who have so warmly interested themselves in the labors of supplying material and correcting proofs, and particularly to those engineers and others who have, unsolicited, expressed their favorable opinion of the different chapters as they have appeared in the columns of the *Street Railway Journal.* To them and to all others who are conscientiously engaged in developing this young industry, this volume is respectfully dedicated.

Since the business is usually entered upon by those who, in respect to maturity of years and opportunity for previous preparation, differ widely from one another, to some a help like this may not be necessary, but to others, the author and publishers have reason to think, it may be useful. Indeed, it was the expressed want for some such help on the part of many engaged in this particular line which prompted the attempt to supply it. The labor, which was undertaken with many fears, has been greater than the result can indicate or measure. But should the work prove of value to the different classes of street railway men and others as outlined, and prompt them to higher attainments in the business, the laborer will have received the hire for which he wrought.

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STREET RAILWAYS:

THEIR

CONSTRUCTION, OPERATION AND MAINTENANCE.

CHAPTER I.

ELECTRIC TRACTION.

Any person of ordinary intelligence who has a desire to become familiar with the application of electricity as a means of transmitting power for propelling street cars, can gain a very good knowledge of the machine and appliances by means of

FIG. 1.—BAR MAGNET.

which electricity, or rather electro-magnetism, is made to propel a car, without knowing very much about the laws and principles underlying the great modern inventions in electricity. Leaving these to the schools and experts, this article starts out, in an easily understood manner, from the fundamental principles of electricity, to enable those who so desire, to learn the essential points relating to electric traction

DEVELOPMENT OF THE DYNAMO.

Magnetism: It has been known for centuries that pieces of a certain kind of iron ore which we now call "lodestone," have the property of attracting iron. It was also early noticed that this peculiar attracting power could be, to some extent, communicated to pieces of steel by rubbing them with lodestones. This attraction was called "magnetism" from Magnesia, in Asia Minor, where lodestones were first found. The term "magnet" is used by scientists to designate a bar of *iron* or *steel* possessing the peculiar properties of magnetism, there being but few other materials (such as nickel and cobalt) which are found susceptible of exhibiting these properties, and even in the case of these to a very limited degree only.

It has since been found that magnetism can be induced or created without the help of a lodestone. A coil of wire carrying an electrical current has magnetic properties similar to those of a lodestone and can similarly magnetize pieces of iron or steel placed near or within the coil, Fig. 14. The magnetism of such a coil is called electro-magnetism. In the case of iron, particularly when soft, there is no retentive power for the magnetism which only persists while the current in the "magnetizing coil" is maintained, and disappears instantly on the cessation of the current. Steel, on the contrary, has a certain retentive power, and continues to exhibit attractive force when the current is discontinued. Hence, magnets made of steel are usually called "permanent" magnets. These are of two forms, viz., the bar magnet, Fig. 1, and the "horse-shoe" magnet, which is merely a bar magnet bent around. (Fig. 2).

FIG. 2.—HORSE SHOE MAGNET.

Polarity: The mariner's compass was founded precisely on the discovery that a piece of lodestone or of magnetized steel, when freely suspended, assumed a definite position. It is now understood

that the earth itself is a large magnet and induces this definite position by attracting the free extremities or "poles" of the "magnetic needle" in the mariner's compass. All magnetized substances, whether permanently or temporarily magnetized, have what is called *polarity*. The pole which tends to point northward, when free to move, is called the north pole. The other is the south pole. Electricians indicate the polarity by the letters N and S. When two magnets are placed near to each other the N pole of one is found to repel the N pole and to attract the S pole of the other; and reciprocally. It is precisely by this attraction and repulsion that motive power is produced by the agency of electricity.

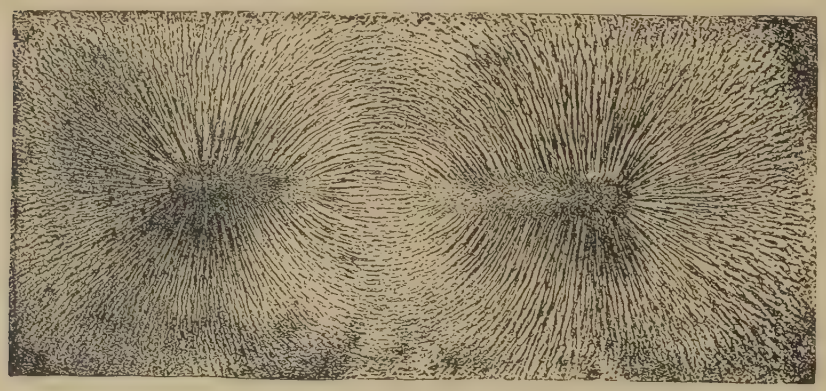


FIG. 3.—LINES OF FORCE OF BAR MAGNET MARKED BY IRON FILINGS.

It is now understood that the phenomena of magnetism are due to an atmosphere of magnetic influence which surrounds the poles, and to a lesser extent, the whole of the magnet. This atmosphere is termed the "magnetic field." If a piece of thin paper is placed over a bar magnet and fine iron filings are sprinkled over it the particles of iron will arrange themselves in regular curves between the poles and so map out, or define, lines in the magnetic field which scientists call "lines of force." See Fig. 3. Fig. 4 exhibits the manner in which the filings arrange themselves about the poles of a horse-shoe magnet. The forms of the curves show not only the direction of the magnetic force but they also help us to draw conclusions as to its intensity. When the force is great the curved lines are thick and sharply defined, and when it is weak the lines are thin and less plain.

The lines of force are also to be found in the neighborhood of wires through which electric currents are passing. They are the outward effect produced by the passage of an electric current, but the most singular fact is that they can also be the cause of an electric current. When a loop of wire is moved in the magnetic field, crossing the lines of force, a current of electricity is generated in the wire composing the loop. The electricity thus generated in the wire is called an induced current and continues as long as the motion lasts. the direction, however, of the current generated in the wire while it is entering the field is opposite to that of the current which is generated when it is leaving the field, or is reversed when the motion is reversed. The current ceases when the wire is at rest.

Just here we learn that motion or power will produce electricity, and it will not be difficult to mount our wire loop on a shaft, and, by means of a crank, cause it to pass in both directions through a magnetic field. Every time the loop crosses the lines of force in either direction there will be a current induced in the wire, and if the shaft be turned very fast these currents or beats of electricity will follow each other quickly in a stream; then, by means of springs or brushes resting on the ends of the revolving wire, we can conduct the currents through a wire circuit from one brush back to the

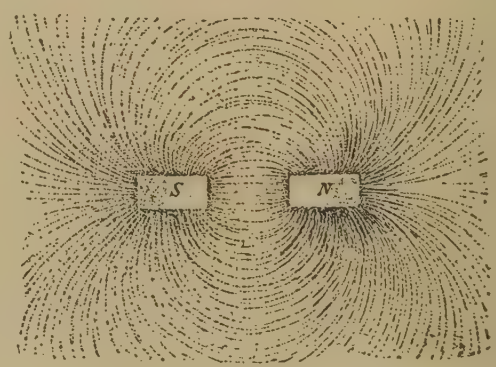


FIG. 4.—LINES OF FORCE OF HORSE SHOE MAGNET MARKED BY IRON FILINGS.

other. Such a machine, Fig. 5, is the simplest form of a dynamo-electric machine or "dynamo," and it consists of a single loop of wire having its ends connected with the two parts of a split metallic tube, shown in Fig. 6, and so mounted that the two parts of the ring embrace the shaft which must be of hard wood or other insulating material, and by means of which it is made to rotate between the poles of a large magnet, the poles of which have concave faces in order that the wire may revolve as closely as possible to them.

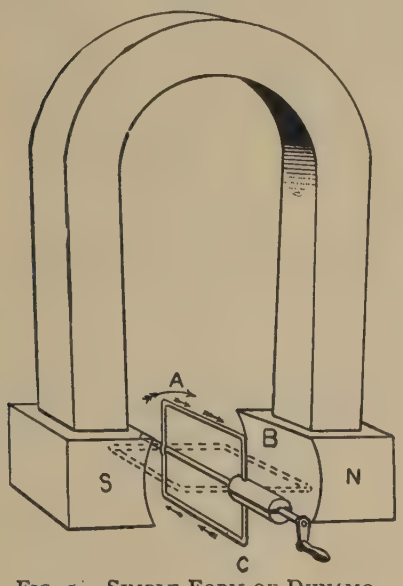


FIG. 5.—SIMPLE FORM OF DYNAMO.

Referring to Fig. 5, if the loop or wire (to which the name of "armature" has been given by the French) has its ends connected to the parts of the split tube (called a commutator) and be rotated in the magnetic field between the poles N and S, in the direction of the large arrow, currents will be generated which are said to flow from back to front (in the direction indicated by the small arrows) during its motion past the north pole from the top to the bottom, but in the opposite direction (from front to back) during its motion past the south pole, or from the bottom to the top. In reality no one knows in which direction, if any, electric currents flow in a circuit; the expression "direction" is a conventional one, as are also the terms "positive" and "negative," but they are convenient expressions and are universally used.

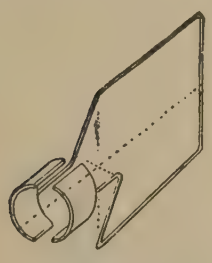


FIG. 6.—SIMPLE LOOP ARMATURE.

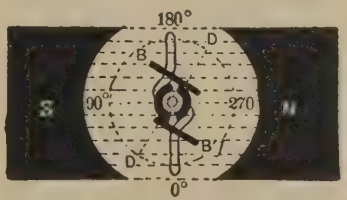


FIG. 7.—COMMUTATOR AND BRUSHES.

In Fig. 7 the letters B and B′ show the metallic springs or brushes on the two halves of the commutator, which are so arranged that one part of the split tube slides out of contact with a brush and the other part slides into contact the moment when the loop passes through the vertical positions where the current reverses itself. By this arrangement the alternating currents or beats induced in the loop are "commuted" and caused to flow in one and the same direction through the circuit That is, the brush B will receive all the currents flowing from back to front, or, as we will now call them, the "positive" currents and B′ will receive all that flow from front to back or the "negative" currents, so that by completing the circuit the current will seem to go out through B and return through B′.

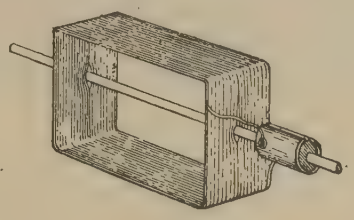


FIG. 8.—SIMPLE RECTANGULAR COIL.

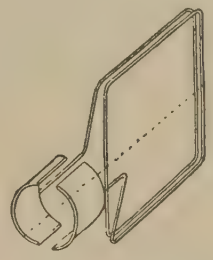


FIG. 9.—LOOP ARMATURE OF TWO TURNS.

It will be noticed in Fig. 7 and some of the subsequent figures that the point where the brushes rest does not exactly coincide with that of the gap between the poles, but that it is slightly displaced in the direction of rotation or in the line D D. This displacement of the brushes is called the "lead" and is necessitated, in some classes of dynamos, for reasons that will appear later on.

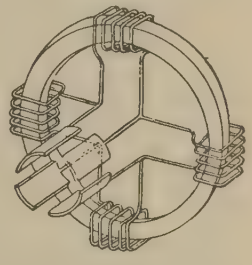


FIG. 10.—FOUR-PART RING ARMATURE.

In place of the single loop a coil consisting of many turns of wire may be substituted, Fig. 8, in each of which an inductive action will be simultaneously going on, making what may be termed the total induced electro-motive force proportion-

ately greater, because the electro-motive force depends on the number of turns of wire in the coil, and the speed at which it is driven. This form, with the addition of an iron core, was given to the magneto-electric machines of the old pattern, and is still used in telephone call machines.

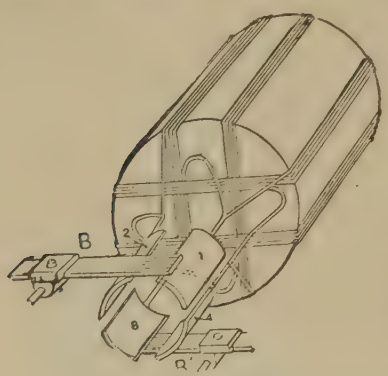


FIG. 11.—DRUM ARMATURE AND BRUSHES.

The same split tube or two-part commutator will answer if a loop of two or more turns be substituted, as shown in Fig. 9. In this case the coils of wire must be separated from each other by being covered with fibres of cotton, silk or some other insulating or non-conducting material, so that the current will not jump across, but will follow the entire length of the wire. We may also substitute for the loop one small coil consisting of several turns wound upon an iron ring, but there must be another coil placed at the opposite side of the ring and connected to the same commutator. There may be placed in the same ring two or more sets of coils at right angles to each other, and, in order to give continuity to the currents, the commutator must have a larger number of parts. (Fig. 10.) Fig. 11 is a sketch of a drum armature with two pairs of coils at right angles to each other and connected to a four-part commutator.

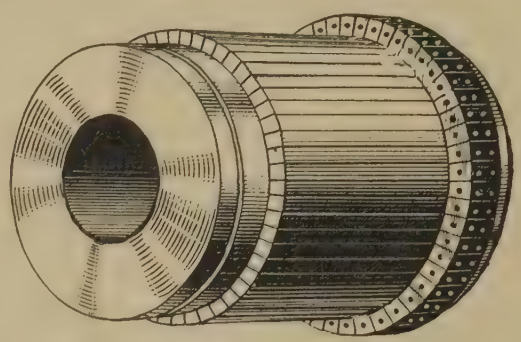


FIG. 12.—COMMUTATOR.

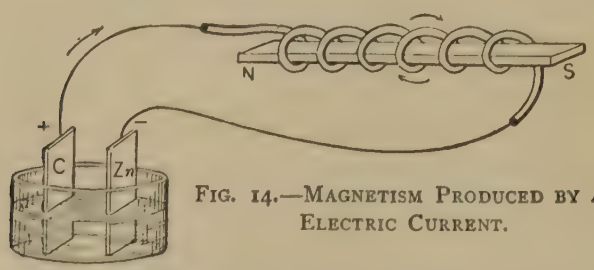


FIG. 14.—MAGNETISM PRODUCED BY AN ELECTRIC CURRENT.

It will be noted in Figs. 10 and 11, that each section of the coil is connected to the next, as well as to the commutator, so that the whole constitutes one single closed coil. The collector, or commutator, segments are not always slices of metal tubing, but are made up of a number of parallel bars of copper, gun metal, or phosphor bronze, insulated from each other and arranged around a shaft from which they are separated by some insulating substance. (Fig. 12.)

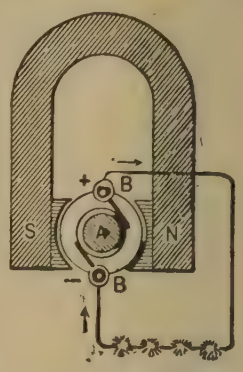


FIG. 13.—PERMANENT MAGNET DYNAMO.

In order to produce a continuous current, the coils on the armature are divided into a very large number of sections, so that they will come in regular succession into the position of maximum induction.

The above figures are types of closed-coil armatures, the coils being connected in series, and there must be as many segments to the collector as there are sections in the coils of the armature.

So far we have described a dynamo machine having very simple parts and one employing a permanent magnet to excite the induced currents, as shown in Fig. 13. This is an old type of machine and is not generally employed.

In order to understand the construction of the modern machines we must retrace our steps. We have seen how magnetism will produce a current of electricity and have stated that electricity will produce magnetism.

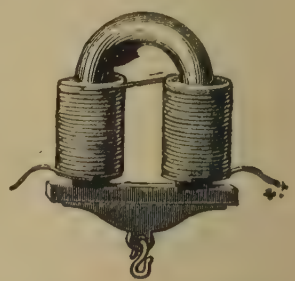


FIG. 15.—AN ELECTRO-MAGNET WITH ARMATURE OR KEEPER.

If a current of electricity, generated by a chemical battery or any other means, be sent through a coil of insulated wire surrounding a bar of soft iron, the bar for the time being

becomes a magnet with a north and a south pole according to the direction of the current, but, unlike the steel bar, it instantly loses its magnetism

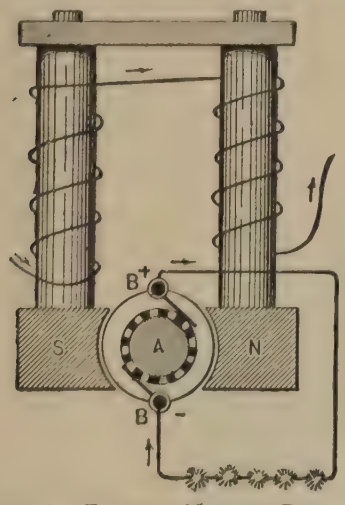


FIG. 16.—ELECTRO-MAGNET DYNAMO.

on the cessation of the current (Fig. 14). The coils of wire may be wound about each pole, or on spools and then placed over the poles (Fig. 15).

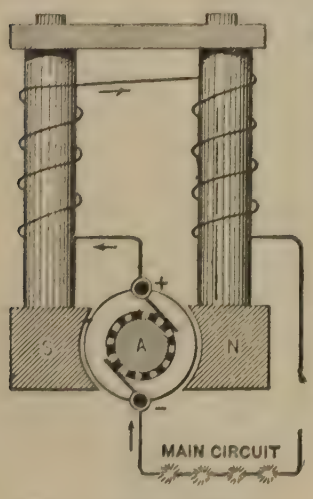


FIG. 17.—SERIES WOUND DYNAMO.

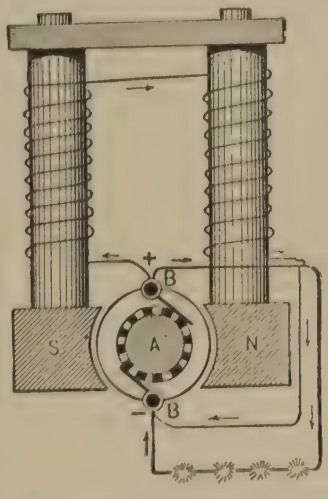


FIG. 18.—SHUNT WOUND DYNAMO.

This is called an electro-magnet, and is employed in electrical machines, such as telegraph instruments, electric bells and signals, as well as in the construction of dynamos. In dynamos this magnet, from the fact that it supplies the magnetic field in which the armature revolves, is called the field magnet, and in practice it is made in a great variety of forms.

A little thought will show that in place of the permanent steel magnet in Fig. 13 there may be substituted an electro-magnet excited from an independent source, either a battery or another dynamo, as shown in Fig. 16. The arrows indicate the course of the current through the wires of the field magnet and also the current generated in the armature as it completes the circuit. Dynamos were, in fact, made this way for

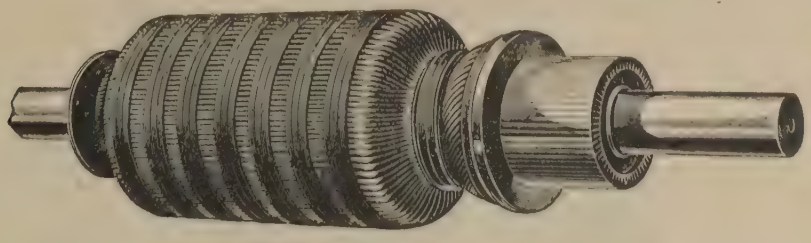


FIG. 19.—COMPLETE ARMATURE.

many years, until the astonishing fact was discovered that the current from the armature could be led around the arms of the field magnet, and

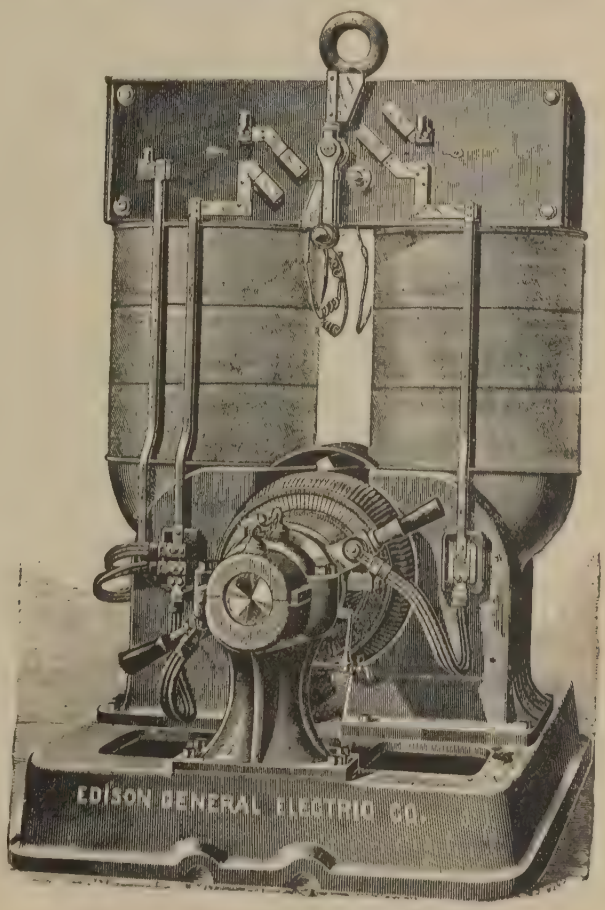


FIG. 20.—EDISON DYNAMO OR GENERATOR.

thus the machine be made to excite its own field magnetism. Such a machine is called a "series," wound dynamo (Fig. 17). Instead, however, taking the entire current around the field magnet, its

arms may be wound with many turns of fine wire which will convey only a small portion of the whole current generated in the armature. These coils being connected to the brushes of the machine constitute a by-pass circuit and is called a "shunt" wound dynamo. (Fig. 18.) The two methods of winding may be combined and the machine is then termed

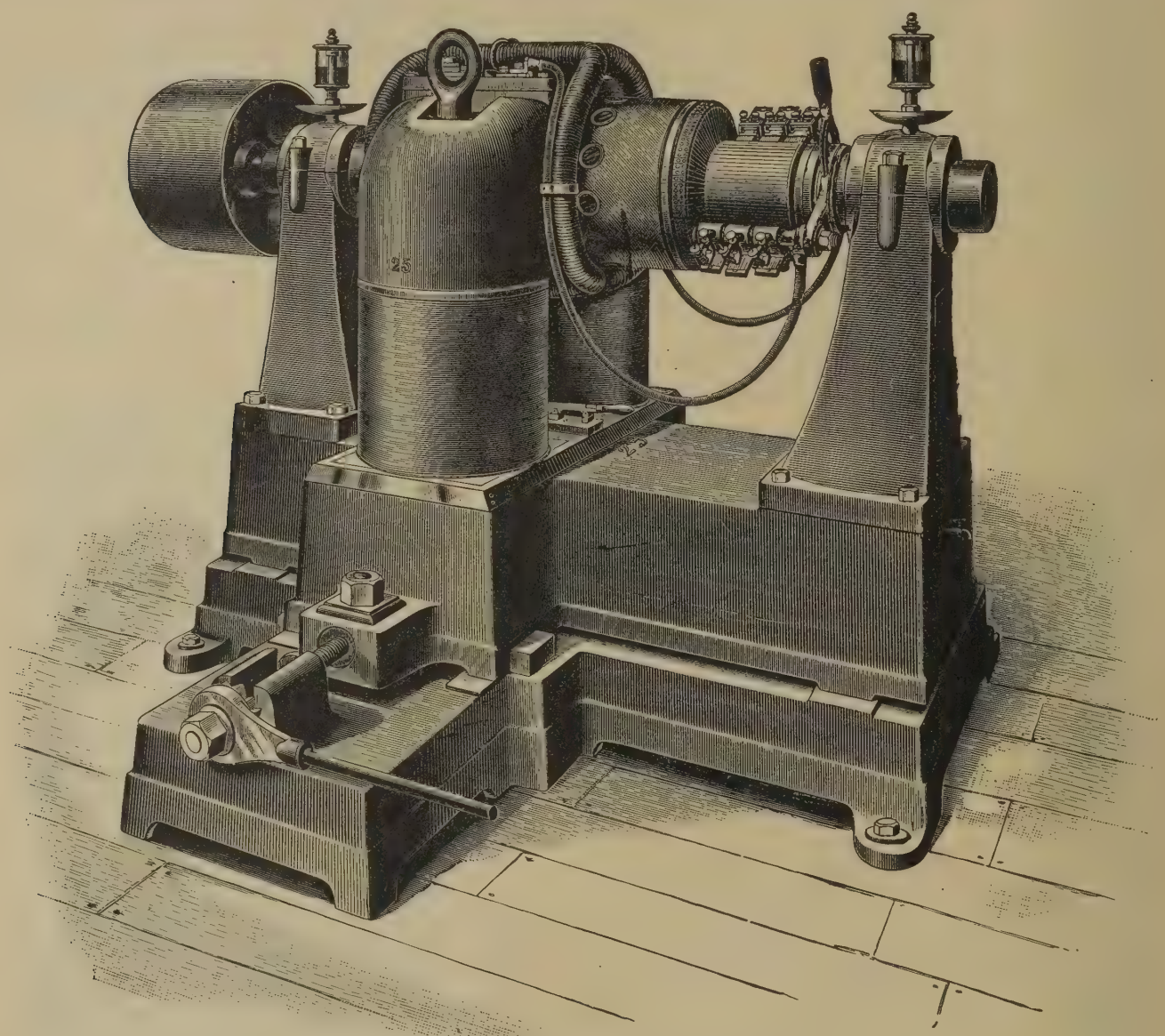


FIG. 21.—THOMSON-HOUSTON GENERATOR.

"compound" wound. Other methods of governing the current are also introduced in some machines and will be readily understood when we study the practical workings of a dynamo.

Before making a practical machine it will be necessary to study a little more closely the organs of the armature, of which there are a number of types, depending upon the shape of the core and method of winding, as already shown in Figs 10 and 11. The first is termed ring armature and the other drum armature. The core of the latter consists of a cylinder of iron, either plain or having lengthwise grooves in which the wires are wound, and the other of an iron ring usually with notches cut in the edges to receive the winding. These armature cores are not usually made of solid iron, but of slit or laminated pieces, in order to prevent the generation of eddy or parasite currents which would cause them to heat.

The drum armature cores are usually built of thin plates of sheet iron, insulated from the shaft and

separated from one another by paper or mica. They are held together by two end plates screwed to the shaft. The cores of the flat ring type are built up of consecutive hoops of sheet iron, separated from each other by paper, mica or some other insulating material.

Instead, however, of winding the drum armature with wire, metal rods are sometimes substituted, but are suitable for electric light work only.

Figs. 19 and 20 illustrate the armature and completed dynamo of the Edison type, and Fig. 21 illustrates a dynamo or generator of the Thomson-Houston type; while Fig. 22 shows a multipolar machine manufactured by the same company.

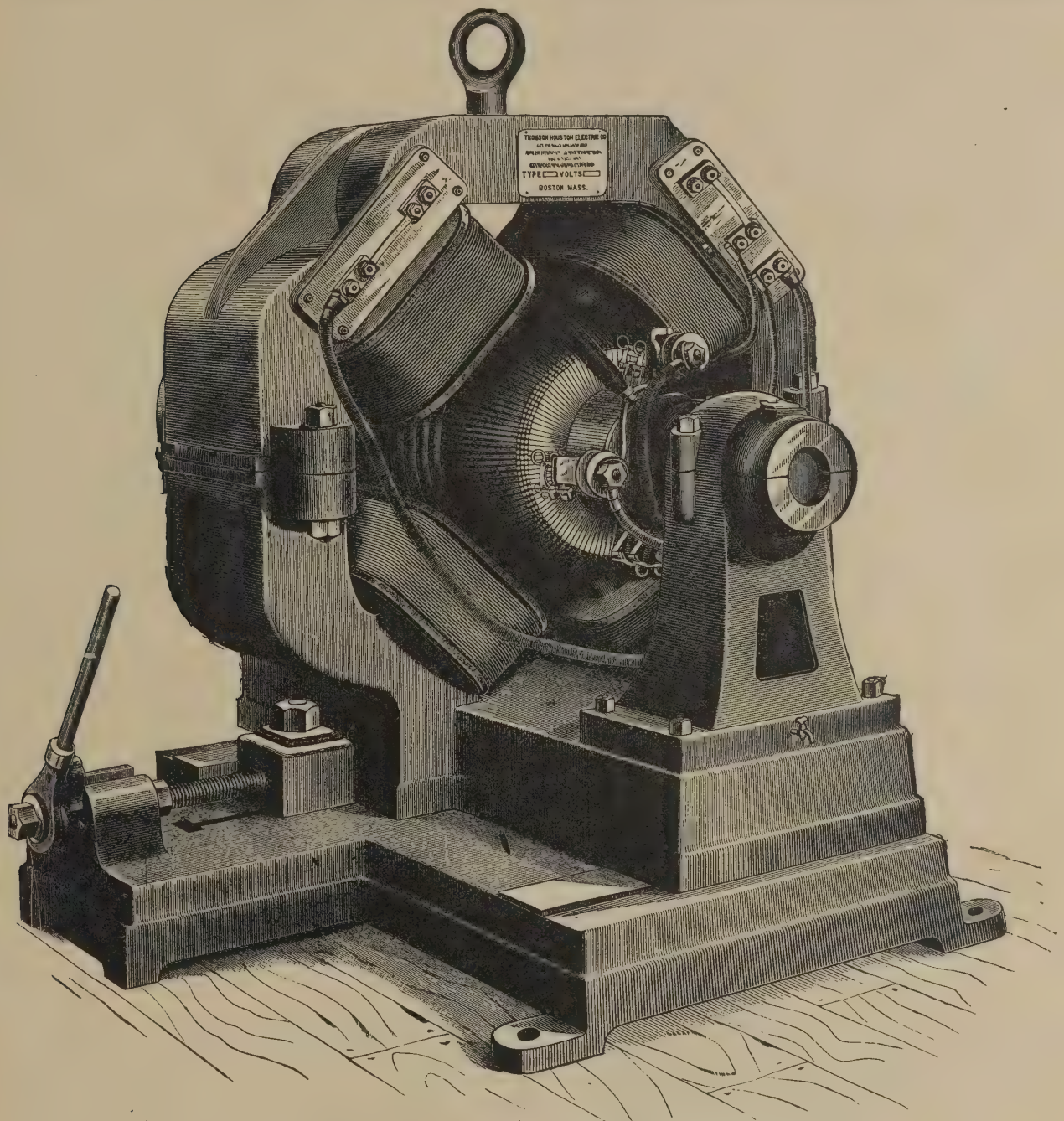


FIG. 22.—THOMSON-HOUSTON FOUR POLE GENERATOR.

An armature core of the ring pattern is shown in Fig. 23. The ring is usually made, as before stated, of thin plates wound concentric, like a roll of ribbon, but has spaces or grooves planed or

milled out of the edges in which the wires are wound. Some makers, however, build up the ring with sections of sheet iron previously stamped out with a die, in each of which the groove is cut, and when laid up in regular order the completed ring has a groove across the entire face. All the iron parts which adjoin the wire of the "bobbins," as the coils of wire are now called, are covered with an insulating material consisting of a layer of strong, heavy canvas saturated with shellac varnish. A sheet of strong cloth inserted, occasionally, separates the layers of wire from each other in the bobbins. All the bobbins are wound in the same direction and the inner ends of opposite bobbins are soldered together. Fig. 24 illustrates a dynamo or generator manufactured by the Short Electric Railway Co. in which the ring type of armature is employed

Other forms of core, armature and dynamo are shown in Figs. 25, 26, 27 and 27A.

The question may arise, where does the electricity come from? No one knows. We do know, however, that pieces of iron and copper wire placed in certain relations to each other, some fixed others moving, produce an inexhaustible supply of electricity, although the parts are insulated from the earth and all surrounding objects; and we know that this electricity may be changed into power, heat and light.

Having learned how electricity may be produced by the application of steam or other power to the shaft of a dynamo, we have next to learn how it is made to do effective work by being conducted through a motor.

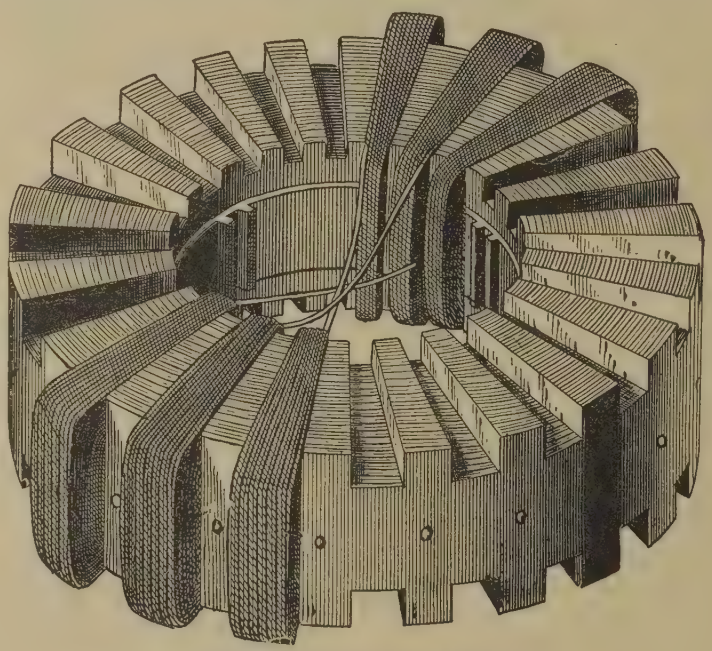


FIG. 23.—RING ARMATURE CORE.

THE ELECTRIC MOTOR.

This is a device for transforming electrical power into mechanical power; and, strange as it may seem, this machine is nearly like a dynamo in all its parts; in fact a good dynamo is usually a good motor and will act as a motor when a current of electricity is sent through its armature. The practical motor, however, depends for its operation more upon magnetic attraction and repulsion than does the dynamo, and the shape and weight of its parts are modified to suit the class of work it is required to perform. A motor will convert into useful work a large percentage of electricity, under conditions depending somewhat on the kind of work it is required to do, but no motor succeeds in turning into work *all* the electricity conducted to it.

We have learned that a magnet will attract the opposite pole of another magnet and will pull it around. It is also true that a coil of wire, carrying a current, is acted upon when placed in a magnetic field, and is pulled around as a magnet is. For these reasons the dynamo may be changed into a motor by directing a part of the current through the coils of the field magnet to produce the poles of the magnetic field and another portion of the current into the separate coils of the armature through the brushes and commutator. The effect of this current is to produce magnetic poles on each side of the armature core directly under the coil through which the current is passing, and also poles in the coil itself. Now, if the brushes are so arranged on the commutator that these poles, formed in the armature, are at right angles to the poles of the field magnets, each pole of the latter will attract the unlike and repel the like poles of the armature, so that the latter is pulled and pushed around. As the armature revolves, however, the brushes transfer the current to the

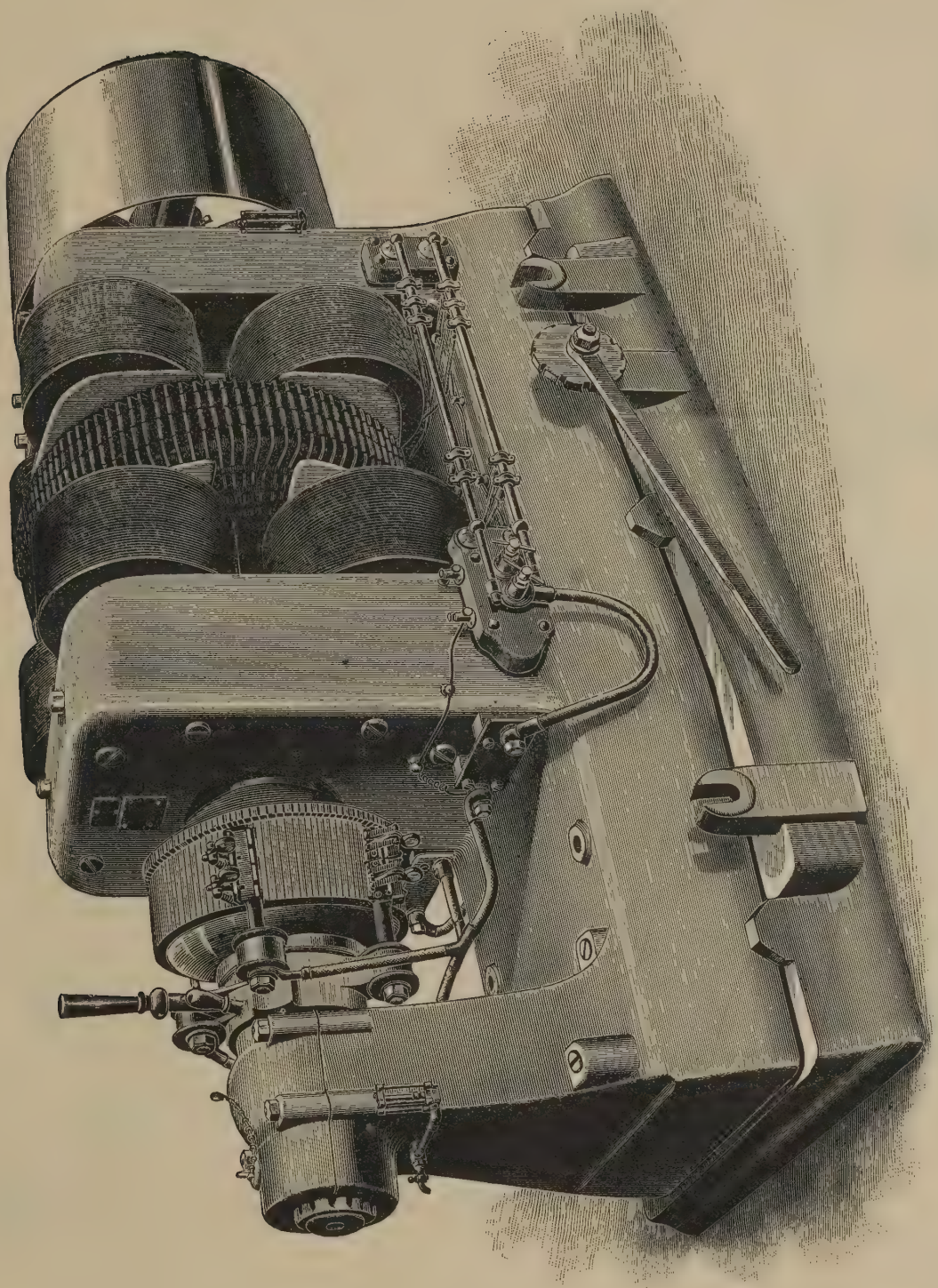


FIG 24.—SHORT ELECTRIC RAILWAY COMPANY'S GENERATOR.

next coil; new poles are formed at the same point, which in turn try to climb up to the unlike poles of the field magnets, but never reach them, for, by the rotation of the commutator, the armature poles are

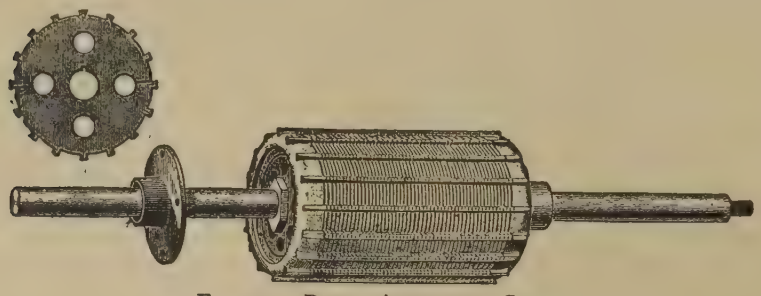


FIG. 25.—DRUM ARMATURE CORE.

FIG. 26.—ORDINARY DRUM ARMATURE.

set back and remain stationary relatively to a fixed point, while at the same time they traverse the entire circumference of the armature.

When the dynamo is run as a generator poles are formed in the armature in the same way, but, in such a position that the field magnets are all the time pulling back; hence it is that the faster the armature of the generator is revolved the more power it requires to keep it in motion.

We have learned that the shape and weight of the parts of the motor are modified to suit the class of work it is required to perform; hence it is that, for street car work, where the motor is to be placed on the truck under the car body, it is usually constructed in a very compact form, as will be seen from the accompanying illustration, Fig. 28, which is known as the Thomson-Houston type of motor and is in use on many electric railways. Fig. 29 shows a dissected motor of the same type, and on the left of the same figure is shown a current controlling device or rheostat.

Having described in a general way the operation of a motor, we have now to see how it is utilized for the propulsion of street cars.

The mechanical methods of connecting the motor to the wheels of the car are among the important points first to be considered.

In the early experiments of electric traction, the motor was mounted on the front platform or on some portion of the car body, and the power produced by the rotation of the armature was transmitted to the car axles by means of belts, sprocket chains, or rope gearing.

These methods having developed some difficulties in operation, direct gearing was substituted and has met with quite general approval. Still other methods, such as friction, worm and differential gear are employed. Some motors are gearless, the armature being mounted on the car axle, and will receive attention farther on.

SELF CONTAINED MOTOR TRUCKS.

These consist of a rigid framework resting upon the journal boxes and carrying a portion of the weight of the motor, the other portion being borne by the axles.

The car body rests upon the frame and is so connected that it may be readily attached or

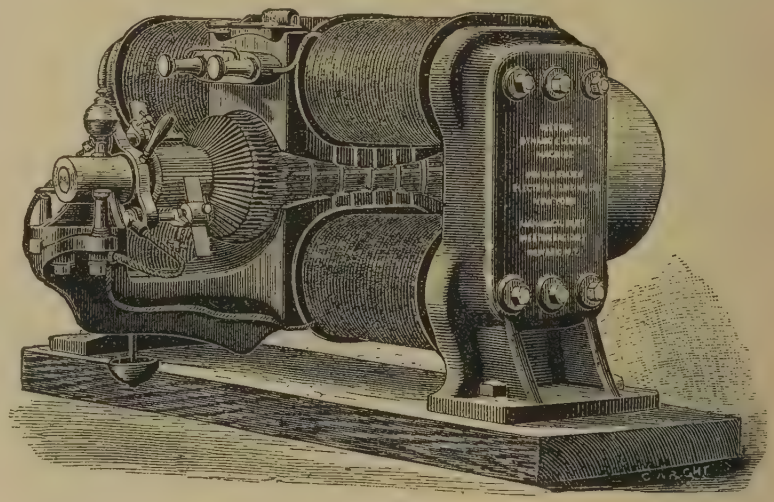


FIG. 27.—THE WESTON GENERATOR.

removed. The important features to be noted in this arrangement are: To provide for an elastic gear connection, to always maintain the journals parallel with each other, and a proper proportion-

ing of the gear wheels, so that the rapid rotation of the armature—2,500 revolutions per minute in some classes—is reduced so as to maintain a suitable car speed.

It has been found expedient in practice, in order to secure sufficient adhesion between the wheels and rails, to mount two motors on each truck, each being geared to an axle independently of the other.

The accompanying illustration, Fig. 30, is a type of motor truck that has met with quite general approval and is equipped with the above described motor.

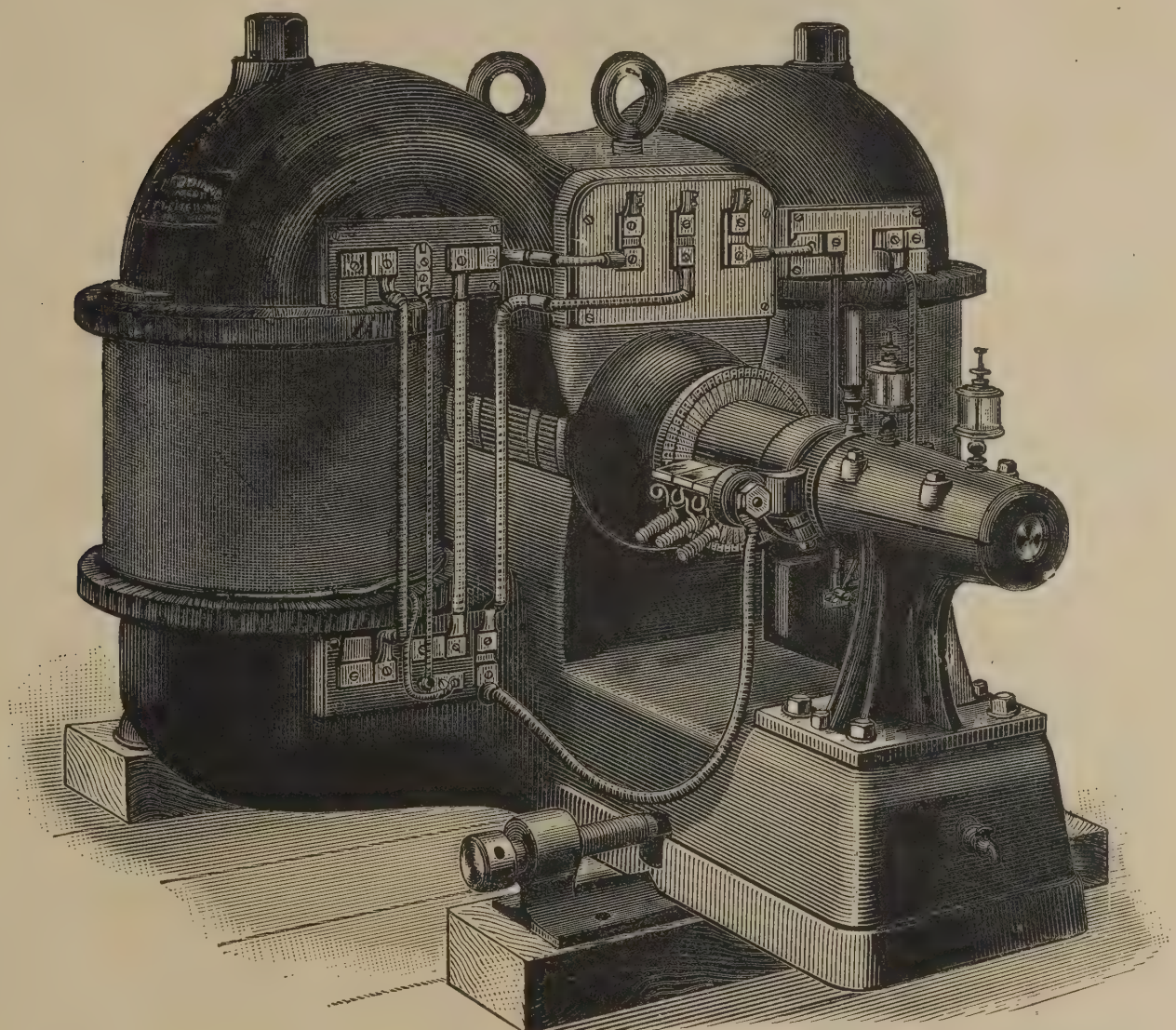


FIG. 27A.—THE RAE GENERATOR.

CONDUCTING CURRENT TO CAR.

In order to transmit the current from the dynamo or generator to the motor on the car, a complete metallic circuit must extend to the car, and back from the car to the generator. As we have already stated, that portion of the circuit leading out from the generator is supposed to convey the "positive" currents and the return the "negative" currents.

Many experiments have been tried to determine the proper location of these conductors and the best means of securing a movable contact with them. On some of the early roads the conductor was placed on the surface and consisted of a third rail mounted on some insulating material through which the positive current was transmitted, and from which, by means of a brush or wheel, the current was taken up, passed through the motor,

thence, by means of the car wheels, to the rails of the track through which it was returned to the generator.

An underground method has also been tried. This consists of mounting two wires or metallic rods, one for the positive and the other for the negative current in a shallow conduit between the rails or at the side of the track. Contact with the conductors so mounted is obtained by means of brushes or plows supported by a thin iron plate or finger hung to the truck of the car and moving along the narrow slot in the top of the conduit.

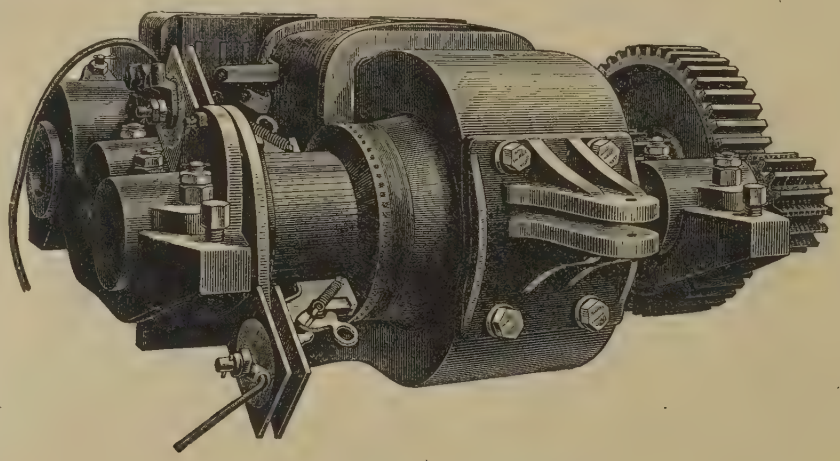


FIG. 28.—THOMSON-HOUSTON MOTOR.

The overhead system is the one that has come into the most general use, and includes the methods of supporting one or both conductors and making contact with them above the car. Of these two methods the single wire under-contact arrangement is the most popular. In this case the positive wire is supported over the centre of the track by means of cross wires attached to poles at the side of the street, Fig. 31, or by means of cross arms

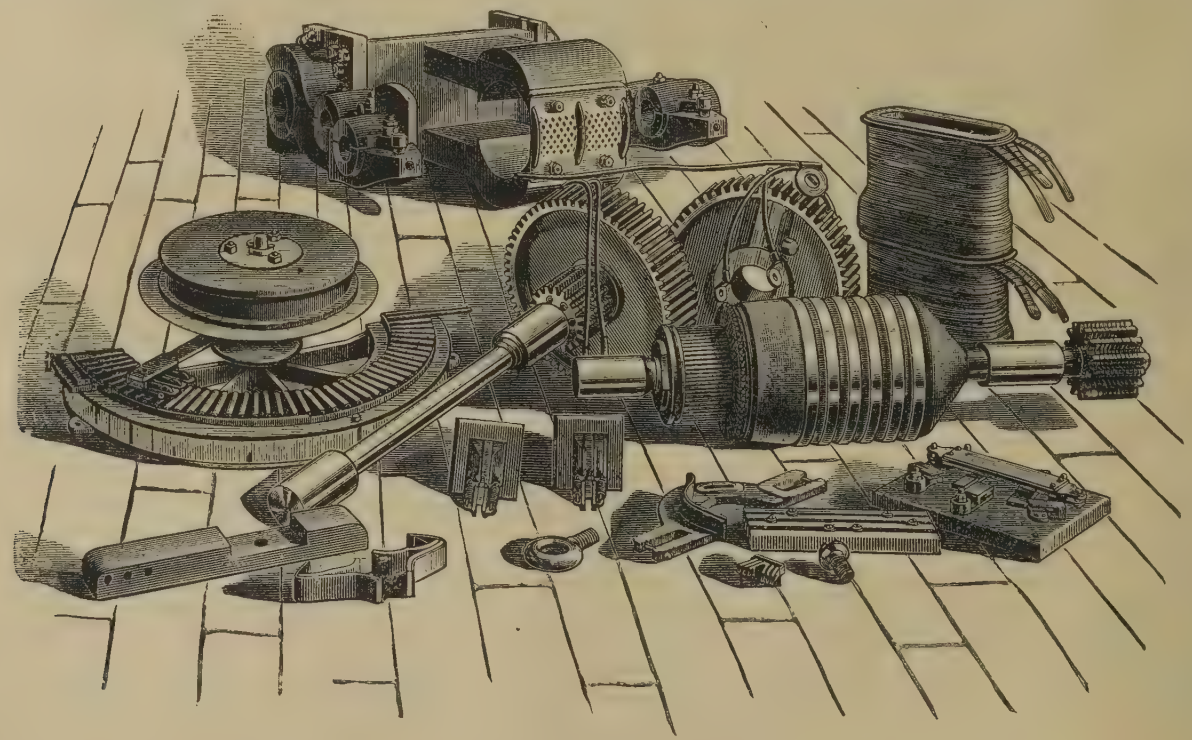


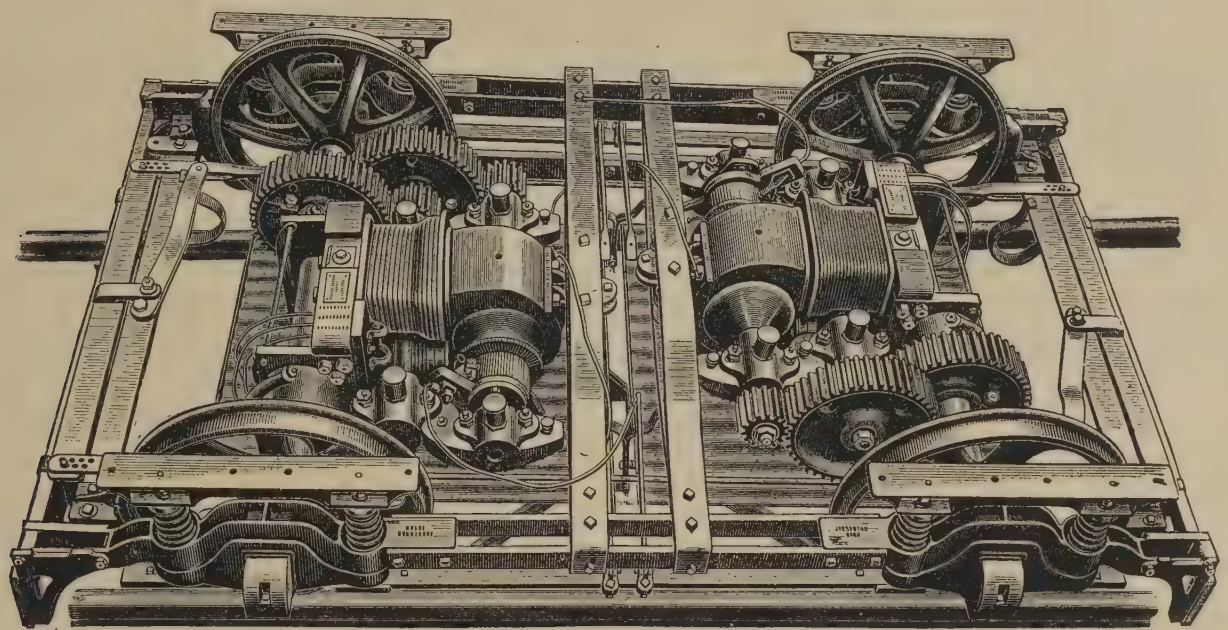
FIG. 29.—DISSECTED MOTOR AND RHEOSTAT.

One brush takes up the current from the positive wire and conveys it to the motor, whence it is returned to the negative wire through the other brush. In this system great care has to be exercised in insulating the conducting wires from the sides of the conduit and also from contact with the slot rails.

on poles placed between the tracks. For single track roads a side pole with brackets is used, as shown in Fig. 32. Figs. 33 and 34 show methods of bracing the trolley wires on the curves.

In the single trolley construction the track rails are utilized for the return or negative current, and for this purpose the ends of the rails are wired together (Figs. 35 to 38), and the rails are usually supplemented by one or more return wires which are buried under the pavement and to which each section of rail, frog or casting is connected by means of branch wires as shown in Figs. 39 to 42. The bonds are connected with the rail by means of rivets which must pass through holes, drilled in the web or base of the rail for the purpose, and be upset into a countersink on one side. The joints of wire is reduced, resulting in an economy of power and an efficient service from the motors. In some classes of soil the resistance of the rail return may be reduced and leakage avoided by driving metal rods or pieces of gas pipe ten or fifteen feet down into the ground, and connecting these rods with the rails or a supplementary wire.

In place of rods, copper ground plates having a surface of from thirty to forty square feet, may be placed at intervals of 1,000 ft. and of a depth sufficient to insure their being always in moist ground.



30.—THOMSON-HOUSTON MOTOR

should be well wrapped and soldered, or the wires may be connected by a metallic coupler, Fig. 43. Where a drawbridge is crossed the rails on either side should be connected by an armored wire, weighted to the bottom of the water with the necessary automatic connections for the rails on the drawbridge.

Galvanized iron wire is recommended for rail bonds and track wiring, for the reason that copper wire, although a better conductor, deteriorates rapidly from electrolysis. In making the track connections the aim should be to return the current to the generator in a direct path and one having as little resistance as possible. By reducing the resistance in the return circuit the total resistance

POLES.

The poles for supporting the overhead wires may be made either of wood, iron or steel, and should be from twenty-six to thirty feet long. Whatever material is used, they should be made strong enough to stand the strain of the cross suspension wire, and, at the curves, the side strain of the conducting wire, or, as it is called, the trolley wire The side poles should stand a direct strain of at least 800 lbs. without deflecting more than four or five inches, and should be capable of standing up under a strain of from 1,200 to 1,800 lbs. without being bent beyond the elastic limit. The strength should be sufficient not only to carry the weight of the suspension and trolley wires but the addi-

tonal weight imposed in case the wiring should be covered by an accumulation of ice and snow.

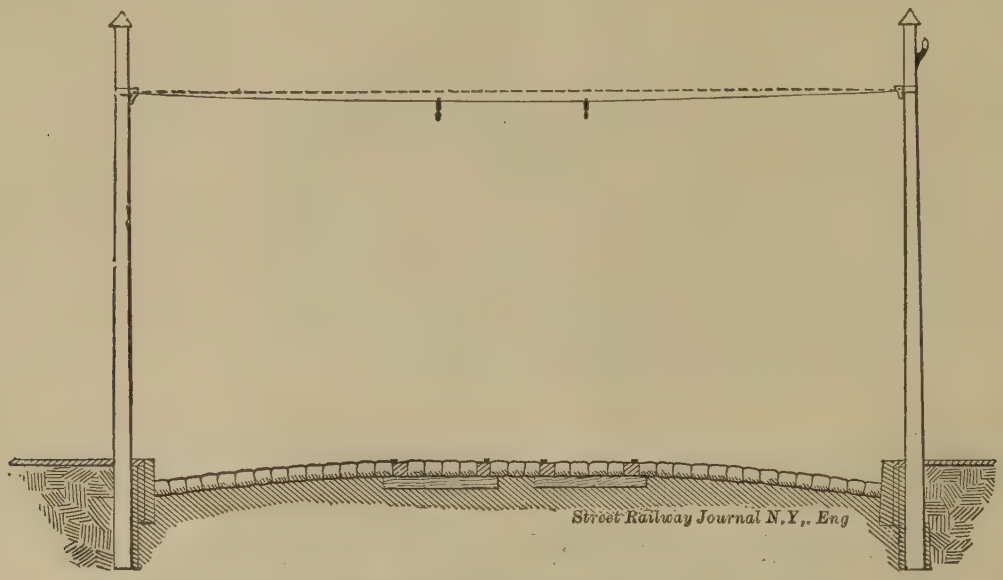


FIG. 31.—SECTION OF STREET SHOWING POLES AND SPAN WIRE.

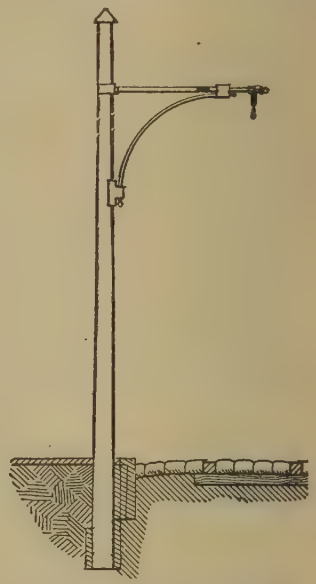


FIG. 32.—SIDE POLE AND BRACKET FOR SINGLE TRACK.

In case wooden poles are adopted, the best timber is chestnut, cedar or Georgia pine. They may be left natural round, or sawn into ornamental shapes and dressed smooth. The top should be coned; and it will be found to be economical to keep them well painted. Wooden poles for use on straight lines should be from seven to eight inches in diameter at the top when finished, and not less than from ten to twelve inches at the base. Larger poles should be provided at the ends of the line, and also for standing the extra pull at curves.

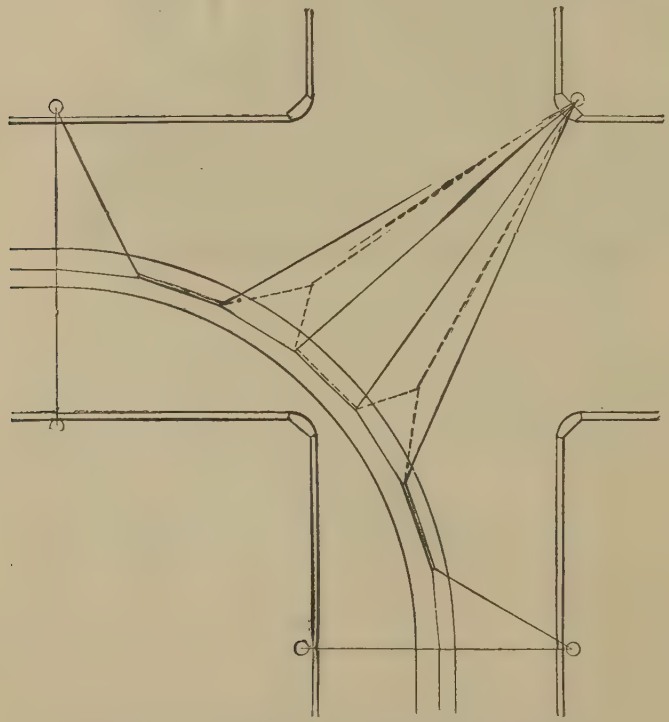


FIG. 33.—OVERHEAD CURVE WIRING FOR SINGLE TRACK CONSTRUCTION.

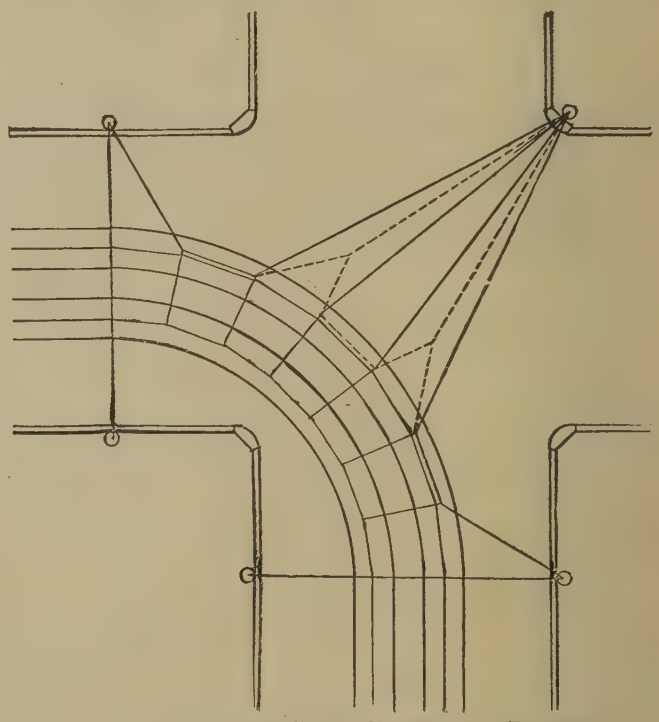


FIG. 34.—OVERHEAD CURVE WIRING FOR DOUBLE TRACK CONSTRUCTION.

Wooden poles should be straight, free from shakes, checks, or large knots. (Fig. 44.)

Iron or steel poles are more desirable, for many

reasons, than wooden poles and may be made more or less ornamental according to taste. For suburban lines wooden poles will answer, but the ornamental type of iron or steel poles is preferable for city streets. A very neat pole is made of three sections of heavy pipe which may be painted an attractive color. The lower section should be from five to eight inches in diameter and the other two sections successively one inch smaller and telescoped from eighteen to twenty inches into the larger. (Fig. 45.) Round iron poles are sometimes reinforced by a truss rod on the outside. This arrangement should be avoided when possible, but in case it is used the lower end of the truss should be anchored to the base of the pole below the surface of the ground and not at the surface. Round poles are sometimes made with an internal web or flange for giving them additional strength on the outside. Such a construction is shown in Fig. 46.

Fig. 47 illustrates a patented form of ornamental pole of lattice work. This type of pole has a very large amount of spring or elasticity and will return to its original position after being subject to a severe strain. These poles have the advantage of being open and free for inspection or painting and can be climbed when necessary.

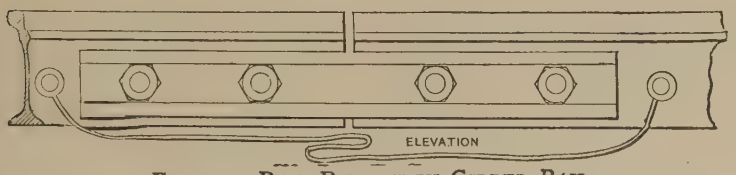


FIG. 35.—RAIL BOND WITH GIRDER RAIL.

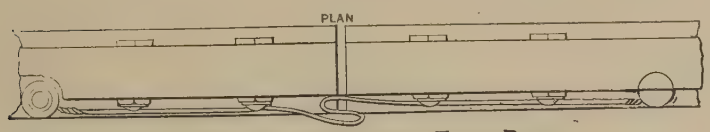


FIG. 36.—RAIL BOND WITH TRAM RAIL.

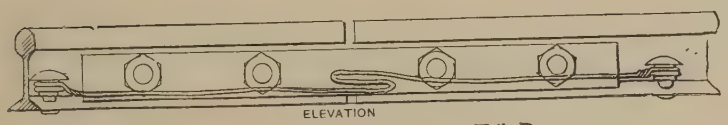


FIG. 37.—RAIL BOND WITH "T" RAIL.

Centre poles, Fig. 48, which are designed for use in the centre of the street between the tracks are made like the side poles—except that the lacing is omitted—as they are not subject to a side strain. To prevent the bending of the cross arms in this type of centre poles a bracing, Fig. 49, is provided which is a combination of bars and angles. An extra heavy pole is provided for supporting the trolley at the end of the line. This type of end centre pole is illustrated in Fig. 50. In addition to the cross arms the end pole is braced from the back, and the arms are provided with loops for securing the end of the trolley line, in place of the usual hanger connection. Other desirable types of poles are shown in Figs. 51 to 54.

Poles are usually placed 125 ft. apart. This distance will depend somewhat upon the size and material of the trolley wire, but it will usually be found the most satisfactory, as the wire should not be allowed to sag over fifteen or eighteen inches.

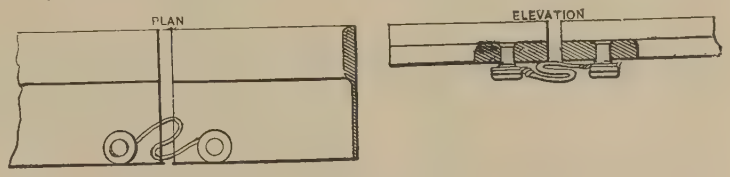


FIG. 38.—RIVETS HOLDING RAIL BOND.

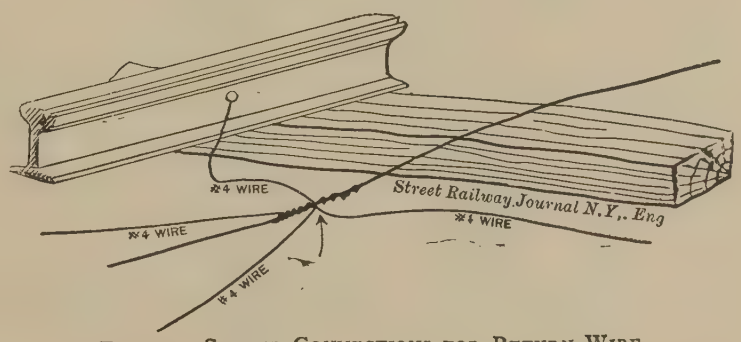


FIG. 39.—SOLDER CONNECTIONS FOR RETURN WIRE.

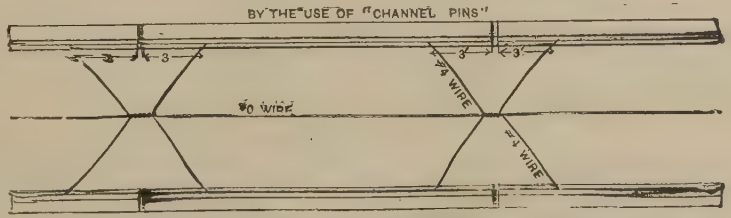


FIG. 40.—METHOD OF CONNECTING RAILS TO SUPPLEMENTARY OR RETURN WIRE.

The pole should be set at least six feet deep in the ground and surrounded by a foundation of concrete, the walls of which should be from twelve to fifteen inches thick; and for straight line work the top of the pole should have about three per cent. of rake away from the street. Where concrete is not used, large stones should be tamped hard against the butt of the pole at the bottom of the foundation at the side away from the rail, and when set on the curb line should bear at the surface of the ground against the curb stone or have a space between it and the curb stone filled with stone. Where there is no curb it is best to place a four by eight stick of timber about three feet long against the rail side of the pole, six inches below the surface. In place of timber, stone may be used. In any event the ground should be solidly tamped.

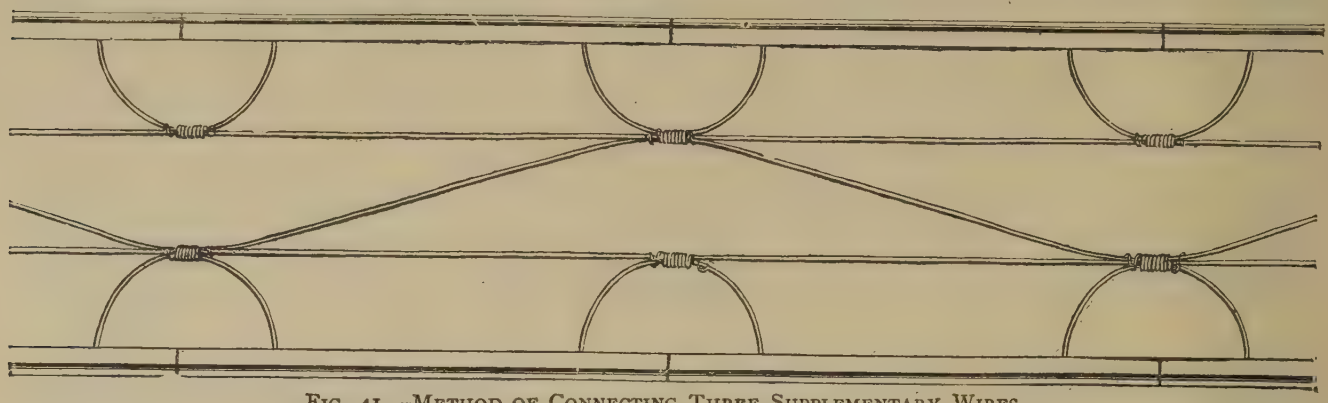


FIG. 41.—METHOD OF CONNECTING THREE SUPPLEMENTARY WIRES.

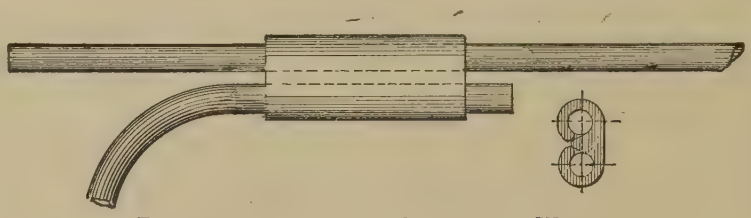


FIG. 43.—COUPLER FOR CONNECTING WIRES.

Poles which support the extra strain on curves should be head-guyed, providing guying will be allowed by city authorities. Guy stubs, or outriggers, should be anchored at least five feet in the ground and the top allowed to extend six feet above the surface. These stubs should be at least eight inches in diameter and should rake well towards the pole top or point directly to it. (Fig. 55.) Care should be taken that there be no metallic contact with a pole or other wires which lead from it. Guys may be made of twisted (double) No. 6 galvanized wire or some equally strong and durable wire.

Near the top of the pole should be provided a device admitting of the most perfect insulation for the suspension wires, and, if guard wires are to be used, with an extension for the guard suspension wires at least ten inches above the trolley suspension wire. There should also be provided appliances for holding the span wire taut. Figs. 56 and 57 show forms of brackets for iron and wooden poles. Those for iron or steel poles have a plug of wood which is inserted in the top of the pole as a means of insulation. This plug is made in a shape to protect from moisture and usually carries a ratchet arrangement for holding the span wires taut. For round wooden poles the bracket may be provided with a clamp as shown in Fig. 57. Lat-

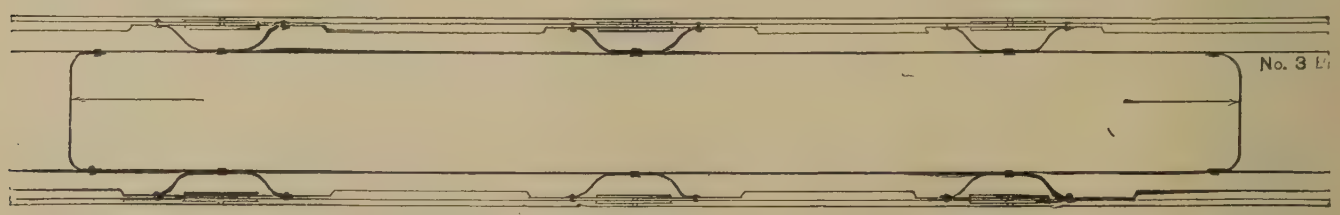


FIG. 42.—SUPPLEMENTARY WIRES AND CROSS CONNECTION.

tice side poles are usually provided with an eye bolt and a nut for adjusting the slack of the span wire.

Figs. 58 to 59D illustrate valuable types of trolley supports, which are suspended from the span wire, as indicated, and support the trolley wire from above without offering any obstruction to the passage of the under running trolley wheel. Figs. 60 to 60B give views of different types of pull-off brackets, while Figs. 61, 62 and 62A are forms of strain insulators, and Fig 63 is a trolley wire current breaker. These should be of the best insulated material and of a shape to shed moisture, prevent leakage and in all cases should be of a material that will not rust. The span wires may consist of stranded wire or of single galvanized steel wire of the size not smaller than No. 5 B. & S. gauge. They must be secured in position so as to have a sag of not more than three per cent. of their length, and should be in position to support the trolley wire at the height of eighteen or nineteen feet from the ground. In no case should they be attached to the pole in such a manner that the slack cannot be readily taken up, and all hangers and eye bolts should have sufficient strength to stand a heavy strain without breaking, and yet should be as light as possible.

FIG 44.—PLAIN WOODEN POLE.

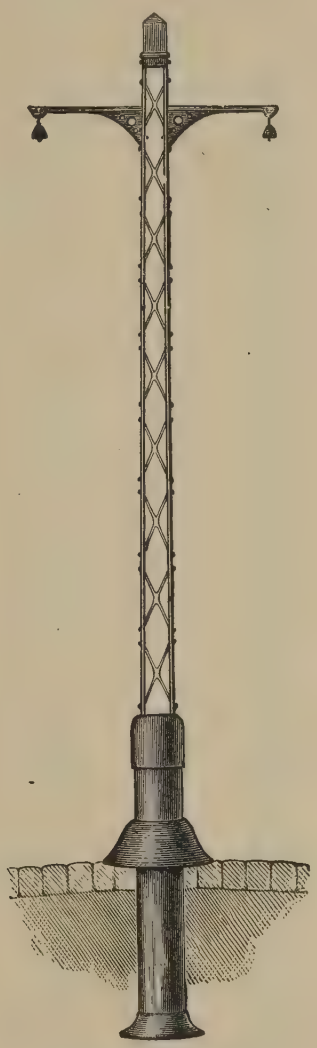


FIG. 51.—ORNAMENTAL CENTRE POLE.

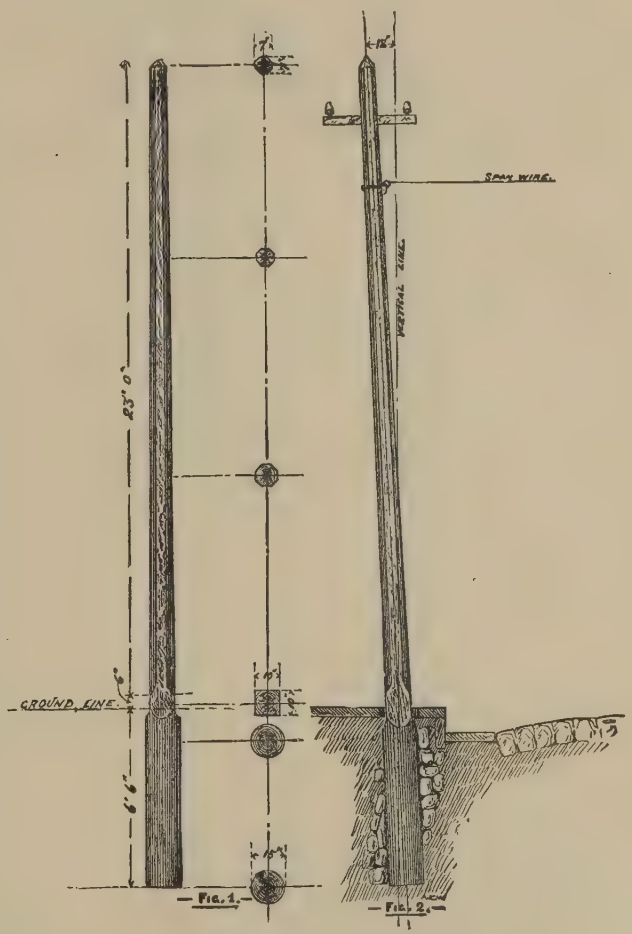


FIG. 44A.—STANDARD OCTAGONAL WOODEN POLE.

The trolley wire should not be smaller than No. 0 (.325 of an inch in diameter), and of hard drawn copper wire or silicon bronze wire. The size, however, depends upon certain conditions which include the number and size of the cars, condition of the track and the magnitude of the grades; hence it is impossible to designate a size of trolley wire which would be just right to meet all requirements. Usually, however, it will be found

economical to use a small wire, and put it up in sections, to each of which the current should be supplied by a feed wire. The frequency of the divisions of the trolley will depend largely upon the peculiarities and situation of each individual line, and will be treated in connection with feed wires.

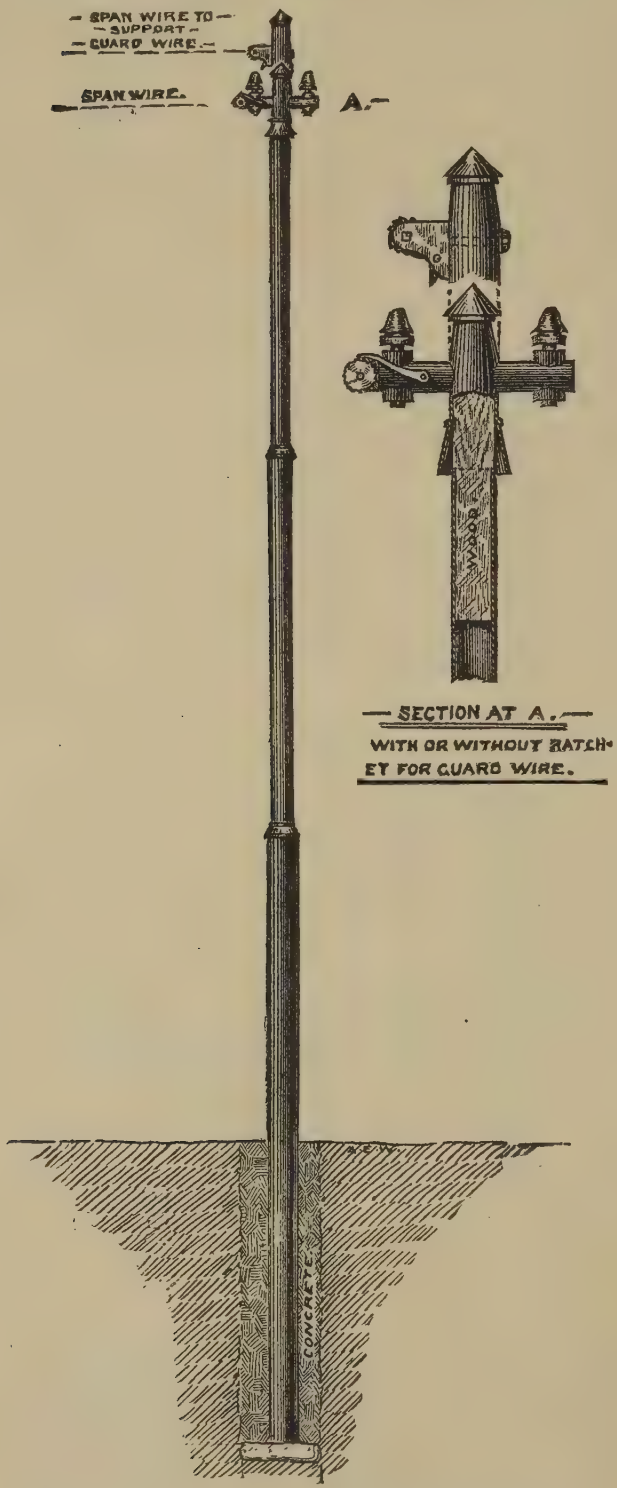


FIG. 45.—WROUGHT IRON POLE WITH TELESCOPED JOINTS.

Strain wires or pull-off wires should be provided to relieve the strain on the trolley wire at each approach to a curve and also at the divisions of the trolley section. They should be of the same material as the span wires, and attached to the trolley by a pull-off bracket midway between the poles, and should lead off through the diagonals of the oblong formed by the four corner poles.

Guard wires should be provided in crowded streets where there is danger of foreign wires such as telephone, telegraph or light wires coming in contact with the

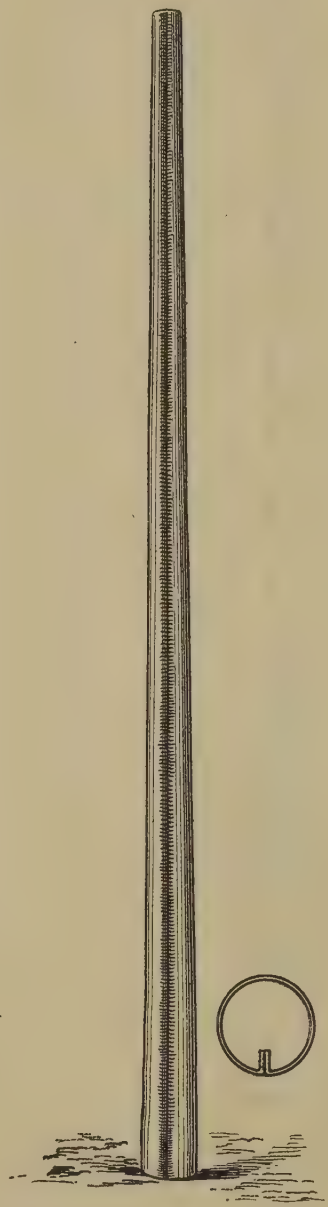


FIG. 46.—ROUND IRON POLE WITH INTERNAL WEB.

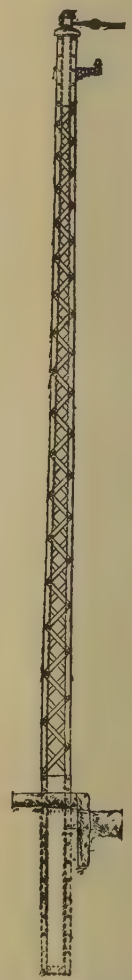


FIG. 52.—ORNAMENTAL POLE.

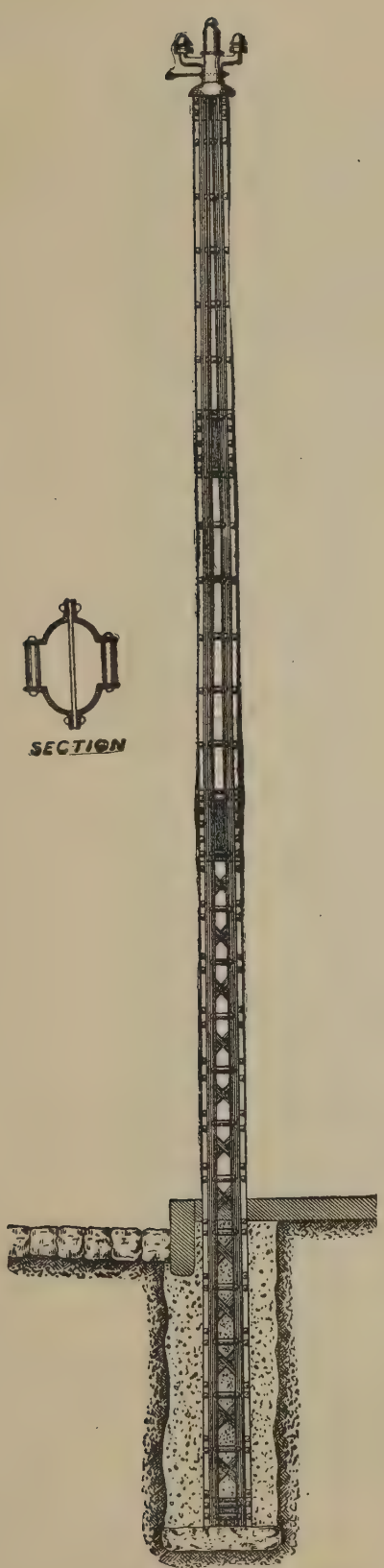


FIG. 47.—ORNAMENTAL "PATENTED" SIDE POLE.

FIG. 49.—CENTRE POLE BRACE.

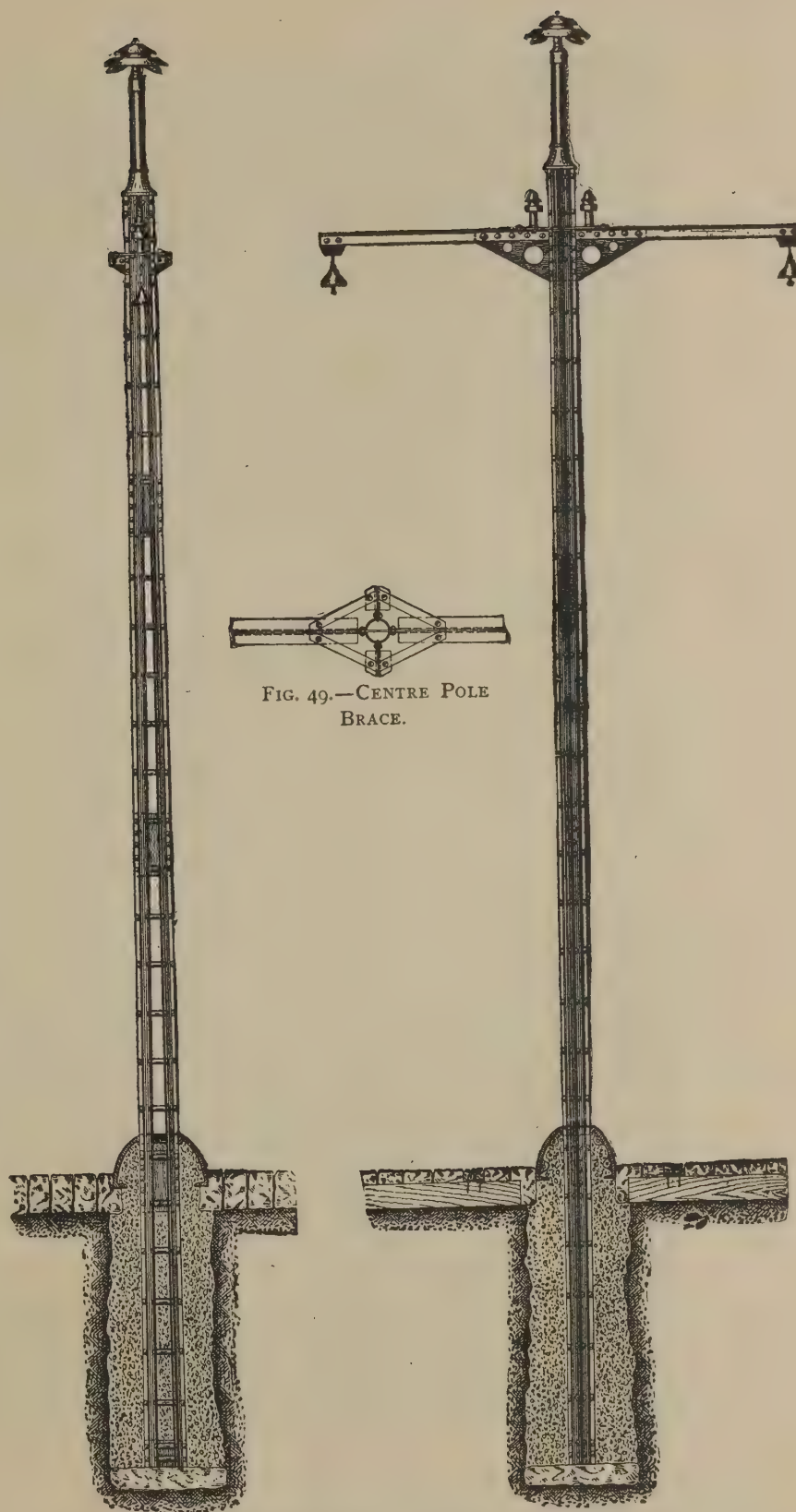


FIG. 48.—ORNAMENTAL "PATENTED" CENTRE POLE.

trolley in case they should fall The guard wires should be of No 8 galvanized wire and supported twenty inches above the trolley wire, should be insulated from the span wires and from the poles, and

Fig. 50.—Patented End Centre Pole.

by a span wire of the same material as the trolley span wire They should be supported from ten to on single track roads there should be two over the trolley wire, two or three feet apart, with the trolley

midway between them. On a double track road three guard wires properly arranged are sufficient to protect the two trolley wires. The necessity of two guard wires or more, in case any are used, will be apparent from the fact that should a foreign wire fall across a single guard wire, in the same vertical plane as the trolley, its weight would be likely to deflect the guard wire sideways so as to bring the foreign wire in contact with the trolley. Guard wires are likely to be a source of trouble, and should only be used in cases where it is absolutely necessary.

Fig. 64 illustrates the usual or "Western Union"

FIG. 53.—TUBULAR IRON CENTRE POLE.

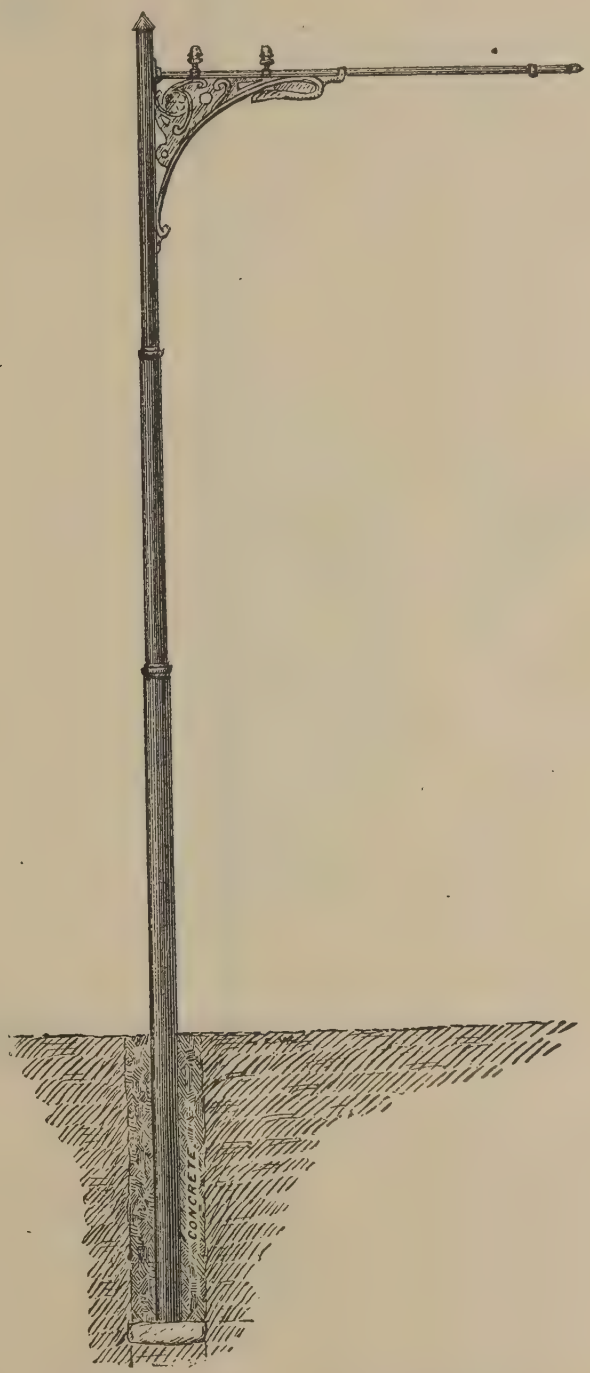


FIG. 54.—TUBULAR POLE FOR SINGLE TRACK.

method of splicing overhead wires. This method of splicing is open to objection in trolley wires, and various other methods have been proposed, the object being to provide as smooth a surface as possible to the passage of the trolley wheel or sliding contact. Fig. 65 shows one method of splicing, which consists of bringing the chamfered ends together and wrapping the joint with fine wire and then pouring melted solder into the interstices. Another method which meets with quite general

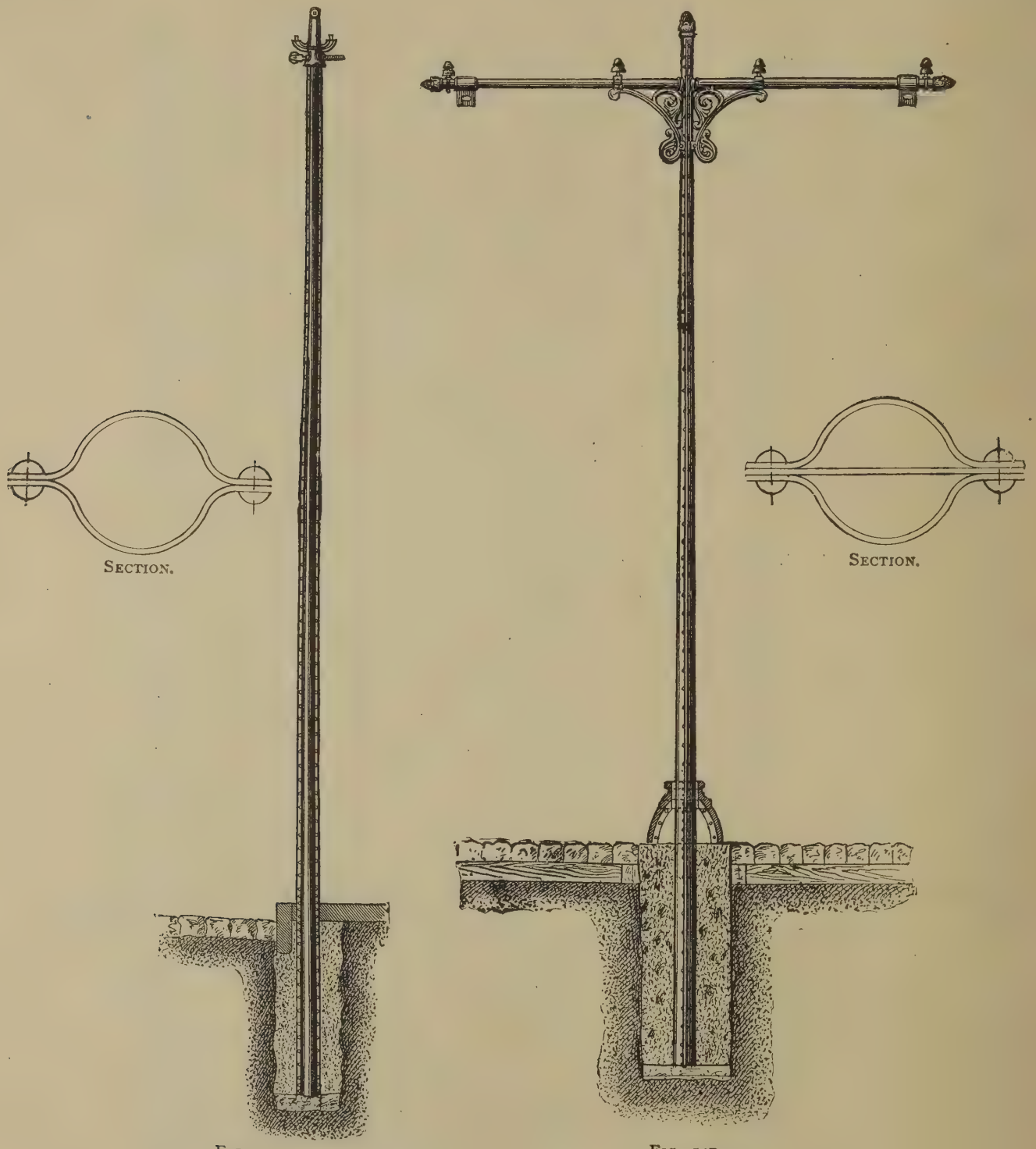


FIG. 54A. FIG. 54B.

LIGHT ORNAMENTAL STEEL POLES WITHOUT HORIZONTAL JOINTS.

favor, consists of inserting the ends in a thin cap or tube and then twisting, as illustrated in Figs. 66 and 67. In some methods of splicing the joint is covered with a brass taper sleeve or pieces of brass tubing cone shaped. These tubes are slipped over the ends of the wire before the splice is made, then the large ends are brought together over the splice and held in place by solder, which is introduced through a small opening made in the side of the tube for the purpose. See also Fig 67A.

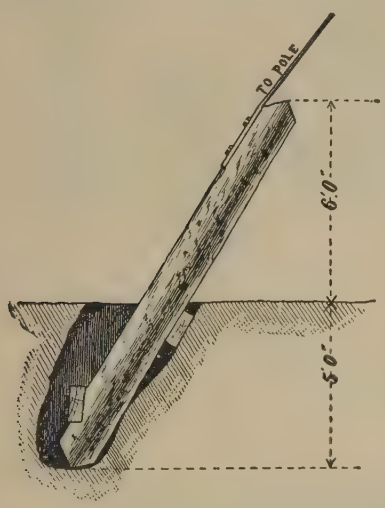


FIG. 55.—GUY STUB.

One method of arranging the overhead switches for turnouts or branch lines is shown in Fig 68. The switches proper, or frog, usually consist of triangular

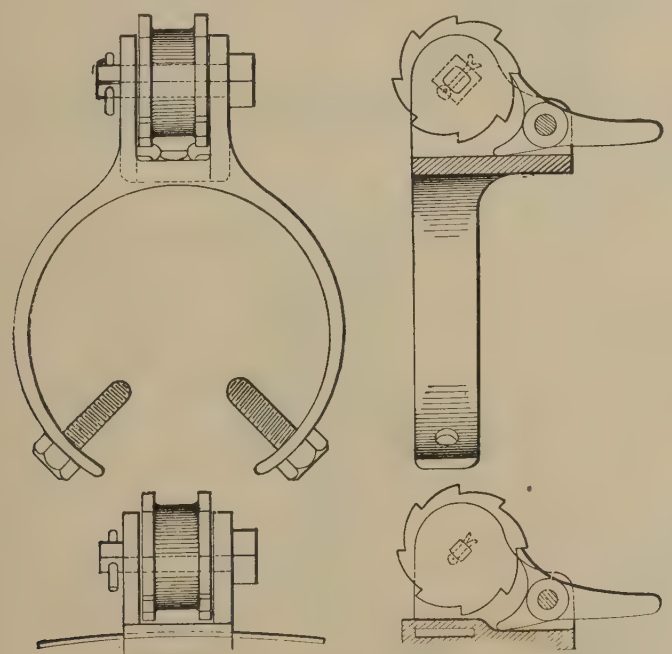


FIG. 57.—BRACKET FOR WOODEN POLES.

shaped pieces of metal (Fig. 68A) having flanges or webs on the under side, placed at the junction of the wires, and so arranged that the trolley wheel, following the car, will take the desired direction without any attention from the conductor. The arrangement of the switch is a very simple and satisfactory one for a single overhead wire, but the switches for double trolley construction are quite complicated; still some have been devised which work very satisfactorily on such lines as employ the double construction.

FEED WIRES.

Ordinarily the trolley wire is not large enough to transmit the power to a long distance without undue loss, hence it is found advantageous to supply the current to the trolley wire at intervals

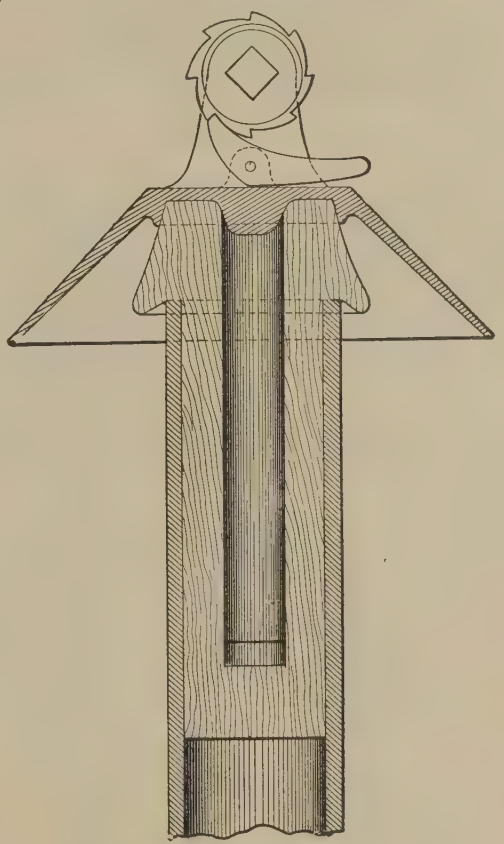


FIG. 56.—BRACKET FOR IRON POLES.

by means of auxiliary insulated feed wires. By this arrangement a nearly uniform potential can be maintained at all points of the line. The advantage of feed wires is graphically illustrated by Fig. 69. In the first diagram a number of gas burners appear on a single supply pipe. The supply is very small at the last light; but in the second, in which a supplemental pipe is used to feed the pipe supporting the burners, the flame is uniform at every point. The same is true with an electric supply to the various cars upon the line.

FIG. 58.—TROLLEY WIRE HANGER.

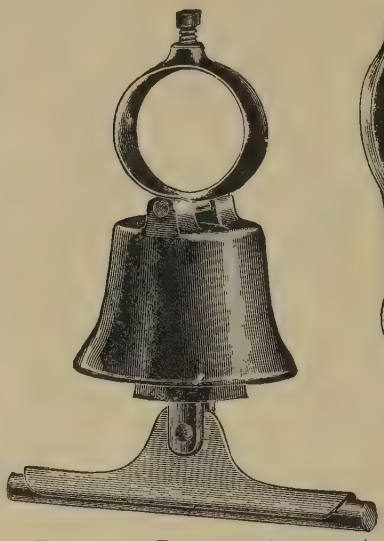


FIG. 59D.—BRACKET ARM INSULATOR.

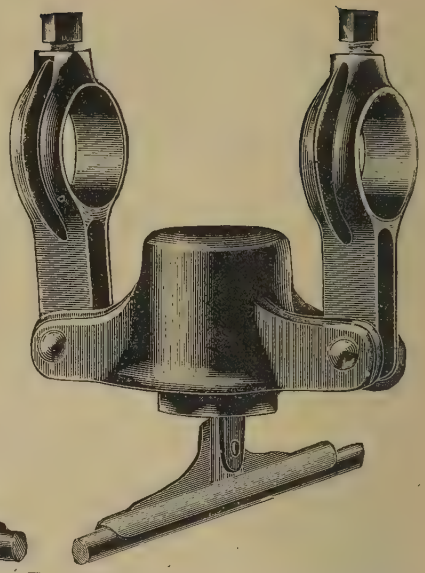
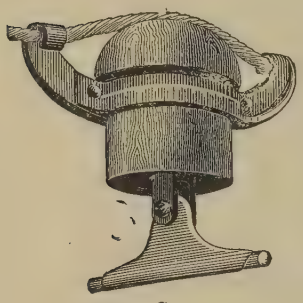
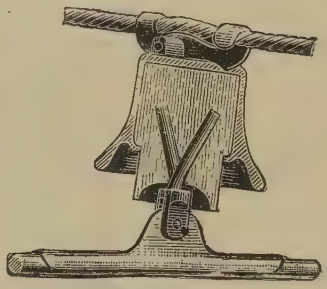


FIG. 59D.—BRACKET ARM INSULATOR FOR CURVES.



TROLLEY SUPPORT.



SECTION.

FIG. 60.—PULL-OFF BRACKET.

FIG. 60B.—PULL-OFF BRACKET.

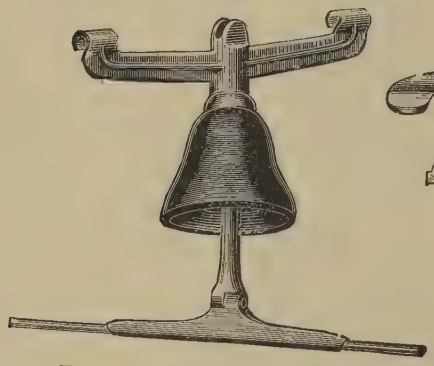


FIG. 59A.—TROLLEY SUPPORT.

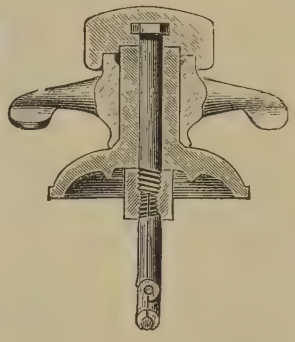


FIG. 59A.—SECTION.

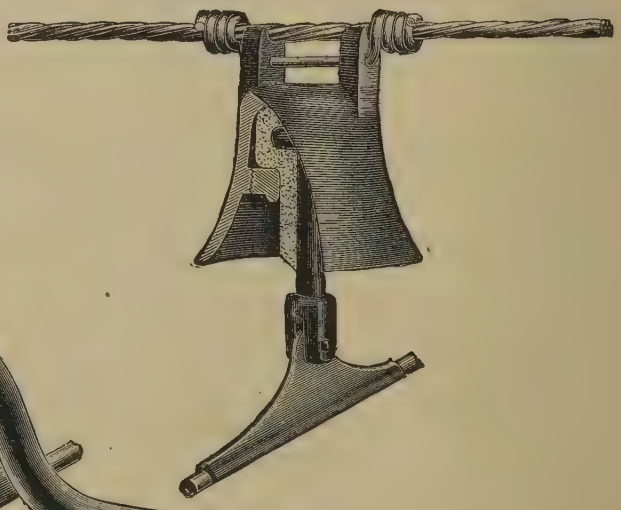


FIG. 59D.—BOX LINE INSULATOR.

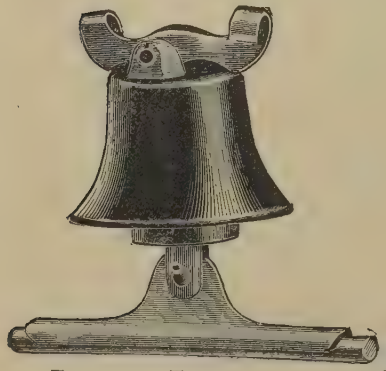


FIG. 59B.—TROLLEY SUPPORT.

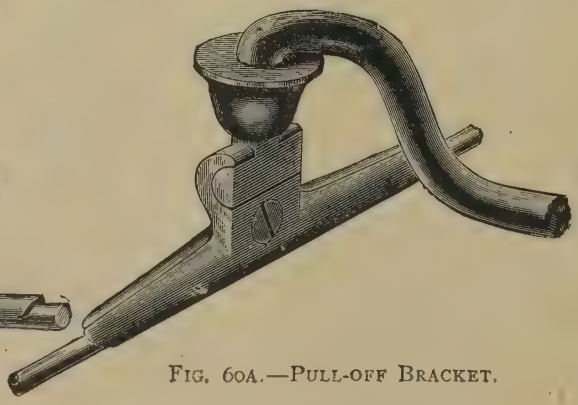


FIG. 60A.—PULL-OFF BRACKET.

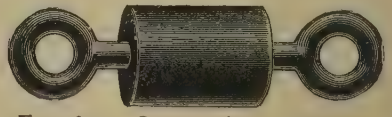


FIG. 62A.—STRAIN INSULATOR.

The feed wires should possess large capacity, and may be carried on the side or centre poles or led through subways between the tracks; when convenient, through cross streets over the shortest route between the power station and the section to be fed. When it becomes necessary to lead the feed wires under water the best armored cables should be used. Connection may be made from the feed wire with the trolley over the span wires by means of insulated hangers. In case the feeder is laid in a subway it may be led up to the trolley by the side of a pole, or if a metal pole is used it may be placed within the pole.

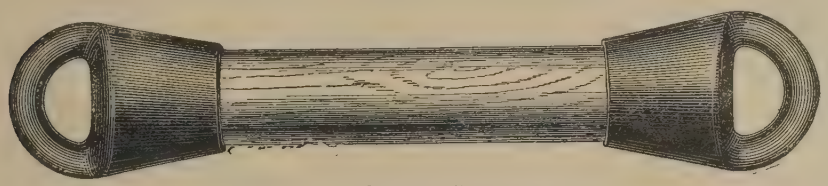


FIG. 61.—BRIDLE INSULATOR.

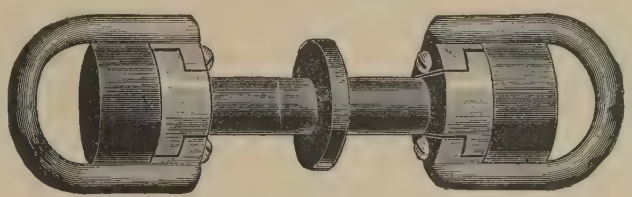


FIG. 62.—STRAIN INSULATOR.

Subways or electric conduits for feed wires are preferably constructed of non-conducting tubing through which the bare conductor can be led. The tubing should be enclosed in a creosoted plank casing, with manholes three or four hundred feet apart. The tubing being laid, there are different methods by which the conductor may be introduced into them; one consists in introducing a light wood or bamboo rod which is inserted in sections, and feruled together, and by means of which a strong rope or cable may be drawn in to be followed by the conductor of any desired length. A second consists of introducing a light cord into the tube by means of a small Sturtevant blower operated by man power. The cord first being wound on a reel is placed in a casing at the end of a hose leading from a blower. To one end of the cord is attached a small leather bag, or the thumb of an old glove, which being introduced into a tube with the closed end forward is readily blown through to the next manhole carrying the cord with it. By means of the cord a heavier cord or rope is drawn in and finally the copper conductor.

Contact of the moving car with the overhead wire, for the purpose of conducting the current through the controlling mechanism on the car to the respective poles of the motor, is made by means of a trolley pole and stand, and the relation of the cars to the circuit is illustrated by the conventional diagram, Fig. 70, from which it will be noted that the current seems to start from the positive brush of the generator G and along the overhead conductor in the direction of the arrows, until it reaches the trolley T of one of the motor cars, which is in contact with the conductor. Here a portion of the current passes down through the trolley to the motors M M, as shown by the dotted lines. Having done its work in the motors it goes on to the rails through the wheels, and by the rails and return wire W, back to the negative brush of the generator. The main portion of the current, which divides at T, passes on to feed other cars upon the line in the same manner, each car taking from the conductor only the necessary amount of current to develop the required power, while the entire return current is carried by the rails and the supplementary wire. The trolley stand consists of an upright, firmly attached to the roof of the car and a long wooden or iron arm or mast, pivoted near one end upon the top of the upright. The

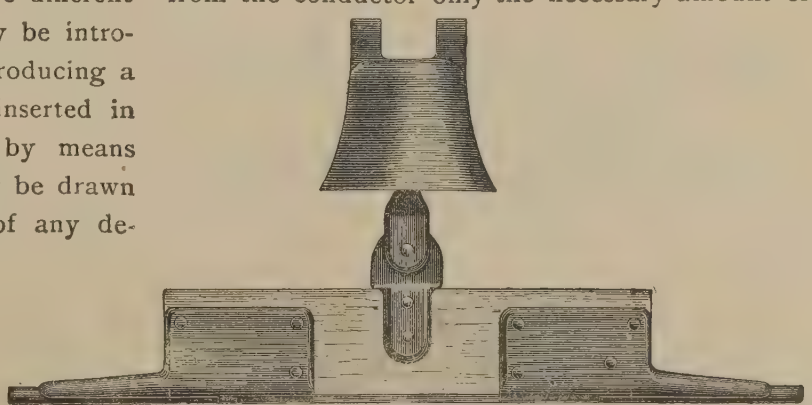
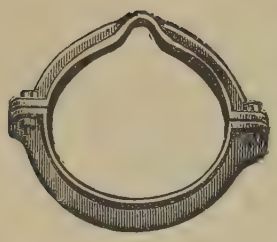


FIG. 63.—TROLLEY WIRE CIRCUIT-BREAKER.

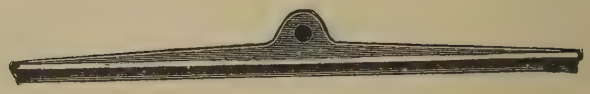


POLE CLAMP.

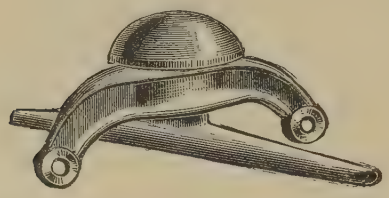
CURVE HANGER.

STRAIGHT LINE HANGER.

PULL-OFF.

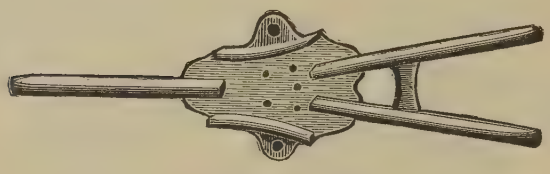


STRAIGHT LINE EAR



COMPLETE EAR BODY OR TROLLEY SUPPORT.

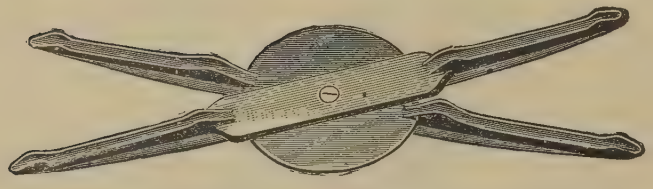
STRAIN EAR.



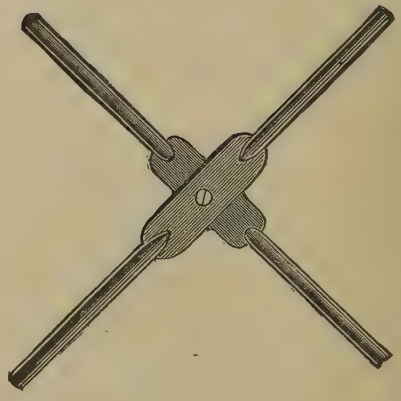
STANDARD FROG.

RIGHT HAND FROG.

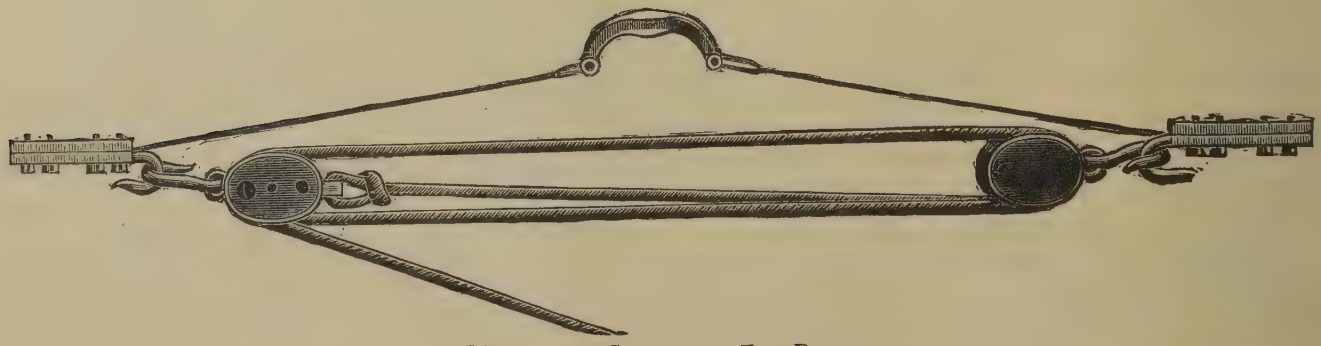
LEFT HAND FROG.



DIAGONAL CROSSING.



RIGHT ANGLE CROSSING.

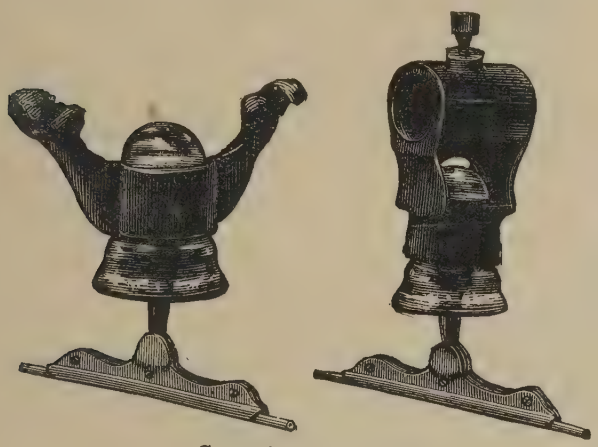


METHOD OF CUTTING IN EAR BODY.

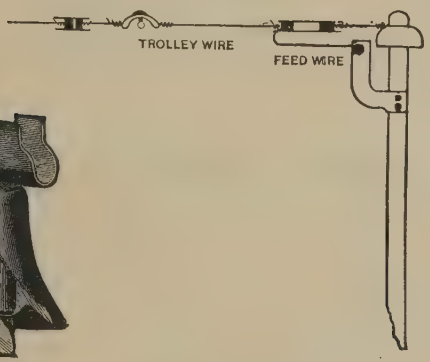
long arm of the mast carries a metallic trolley wheel which is held firmly up against the under side of the conductor by strong springs attached to the short end of the arm and connected with the base of the standard.

The mast, springs and attachments are all free to swivel upon the upright.

An insulated wire imbedded in the mast conducts the current from the trolley wheel to the

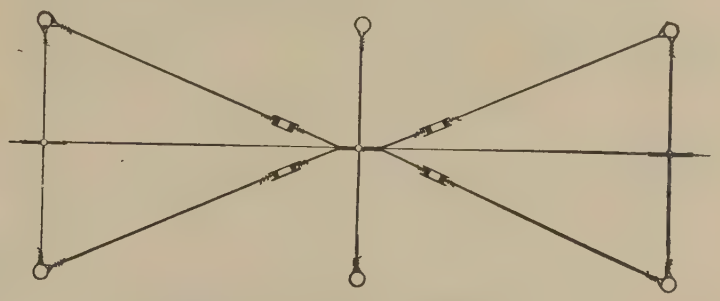


Glass Insulation.

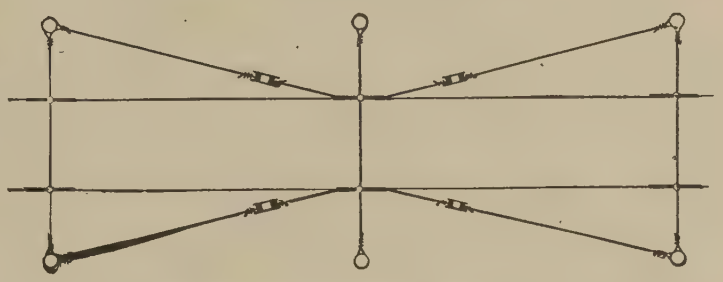


Method of Cutting in Side Feed.

Feed Wire Insulator.



Method of Anchoring Single Line.



Method of Anchoring Double Line.

Method of Setting Frog.

contact with the positive wire and the other with the negative, and by this means the current is conducted from one wire to the motors and back to the other wire.

We have now to consider the wiring of the car and learn just how the wires are to be connected with the switches and with the poles of the motors.

Usually a switch on each platform directs the controlling switches on the car. In place of a trolley wheel, however, a sliding contact may be obtained by means of a carbon lined metallic brush at the end of the trolley pole and shown in Fig. 71. Figs. 72 and 73 illustrate different types of trolley wheel, pole and stand.

Instead of the single overhead wire and rail connections for the return current, the necessary metallic circuit is sometimes formed by two overhead wires placed five or six inches apart. In this case two trolley wheels or two masts, each carrying a wheel, are required. One wheel is run in contact with the positive wire and the other with the negative, and by this means the current is conducted from one wire to the motors and back to the other wire.

We have now to consider the wiring of the car and learn just how the wires are to be connected with the switches and with the poles of the motors.

Usually a switch on each platform directs the current to both motors, and controls the speed and direction of the car. In addition to the switch, however, it is necessary to provide means for controlling the flow of the current through the motors, and this is one of the most important factors in the operation of electric cars.

A great many schemes have been proposed, but on this point there is a radical difference among electricians. One of the most prominent systems effects the controlling influence by a peculiar winding of the field magnets, and will be described later on. In other systems the control of the cur-

rent is made through what is known as a rheostat or resistance box; this prevents an abnormal flow of current through the armature and enables the motor to start up gradually. (Fig. 74.)

FIG. 64.—TELEGRAPH JOINT.

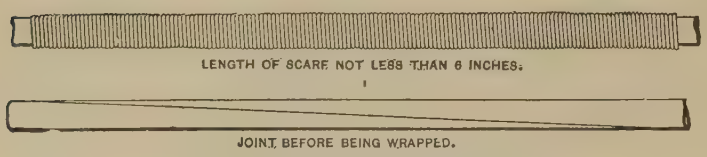
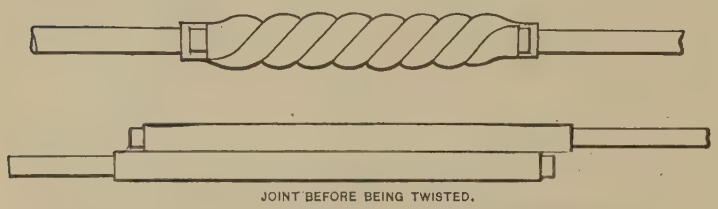


FIG. 65.—TROLLEY WIRE JOINT.



FIGS. 66 AND 67.—FEEDER AND TROLLEY WIRE JOINT.

As will be seen from the figure, the rheostat is constructed in the form of a half circle and is mounted under the floor of the car, as shown in Fig. 75. The resistance consists of small pieces of thin sheet iron cut in the form shown in Fig. 76. These pieces are placed side by side, separated by mica, and are so arranged that they are connected in series throughout the rheostat. At proper intervals contact pieces of heavy sheet iron are provided, as shown in Fig. 77, and the whole is secured in a semi-circular iron case thoroughly insulated with mica throughout.

At the centre of the semi-circle a vertical shaft is placed, having an arm which carries a contact brush. This brush is made of independent iron fingers pressed down by springs. By means of a pulley and a wire rope or link belt connecting with the switch stand on the platform the shaft is turned and the brush is made to slide in either direction over the corrugated surface. It will be seen that if the positive wire is connected to one side of the rheostat, and the wire leading to the motor is attached to the brush when the latter touches the opposite side of the rheostat all of the resistance is introduced and the motor starts up slowly. To increase the speed the brush is moved along over the surface of the rheostat cutting out one section after the other, thus decreasing the resistance, so that when full speed is attained all the sections of the rheostat are cut out, leaving no idle resistance in the circuit.

The peculiar construction and arrangement of the brush insures good contact; and to prevent the formation of an arc when the brush is thrown entirely off the rheostat, a magnet is sometimes provided which automatically blows out the arc. In order that an exceptionally high speed may be attained, the last segment of the rheostat is so connected with a part of the field coils that when the brush is in contact with this section the latter are cut out, thus reducing the strength of the field and causing the armature to revolve faster. The speed which will be attained by the car when the brush is in contact with the last segment, depends upon the winding of the motors, which is usually gauged for about twelve miles per hour.

FIG. 67A.—SPLICING EAR.

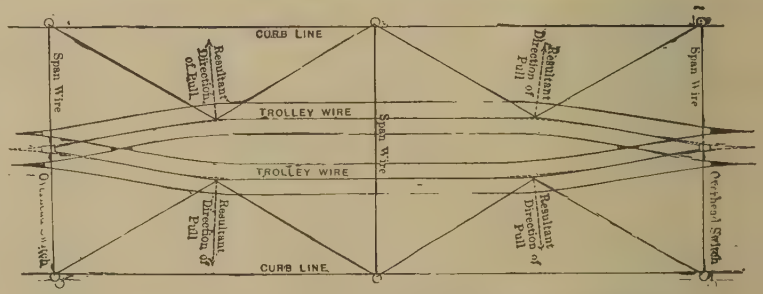


FIG. 68.—OVERHEAD WIRING FOR SINGLE TRACK TURNOUTS.

FIG. 68A.—FROG FOR OVERHEAD SWITCH.

We have previously stated that a motor is put in operation by conducting a part of the current through the coils of the field magnets and another portion into the armature. This is true in case of

a "shunt" wound motor, but with a series wound motor, which seems best adapted for street car work, all of the current may be directed through

This is just what it does do, and as soon as it is set in motion it begins to work as a dynamo on its own account and sets up a current in the circuit in

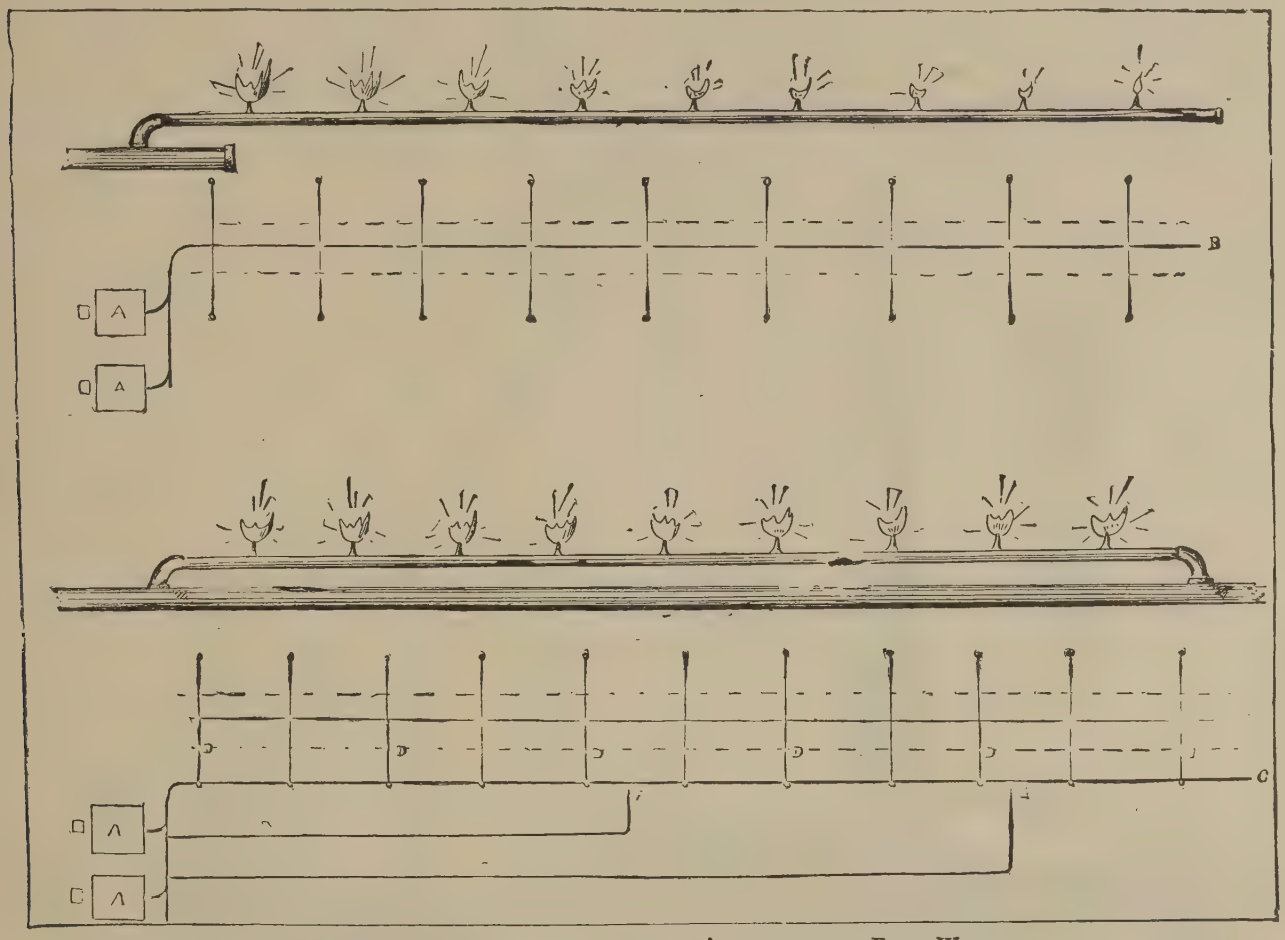


Fig. 69.—Diagram Illustrating the Advantage of Feed Wires.

tne armature and then through the coils of the field magnets or *vice versa.*

The question has doubtless occurred to the

the opposite direction to that which is driving it, and this counter electric action is proportional to the velocity of rotation and the magnetism of the

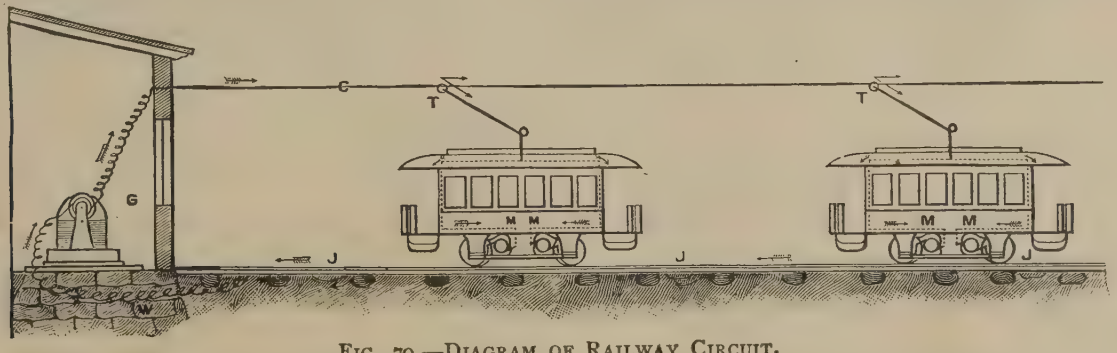


Fig. 70.—Diagram of Railway Circuit.

reader, If the revolution of the armature in a dynamo produces an electric current why does not the spinning round of the armature of a motor, which is like a dynamo, also generate a current?

magnets. Hence it is that the efficiency of a motor in utilizing the energy of the current depends largely on the relation of the electro-motive force which itself generates when rotating, and the elec-

tro-motive force or *pressure* at which the current is supplied to it. This fact, however, does not detract from the efficiency of the motor, as might be supposed, but it is an absolutely necessary factor in the output of the motor; it furnishes, so to speak, a foothold or rest against which the current can brace in its efforts to push or pull.

A motor may be reversed by reversing the current through the armature or through the field magnets; usually it is done through the armature and is accomplished by means of the controlling device.

In the early experiments with electric traction two methods of arranging the cars in a circuit were employed; they are known as the "series" and the

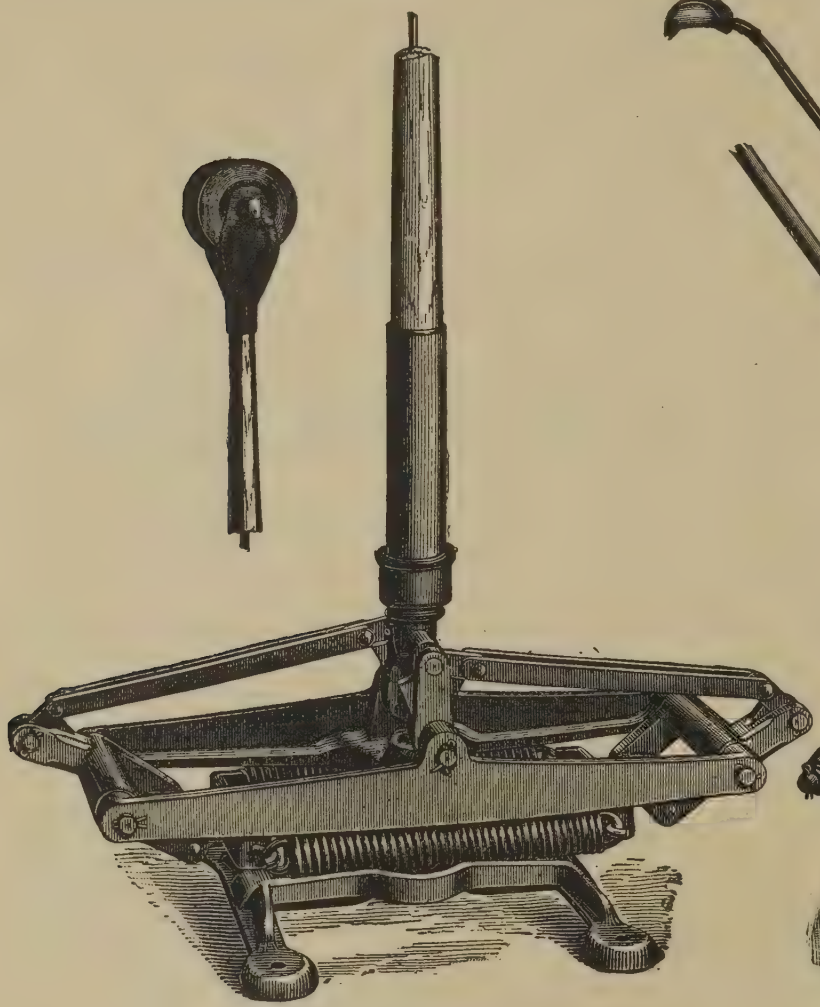


FIG. 72.—TROLLEY STAND.

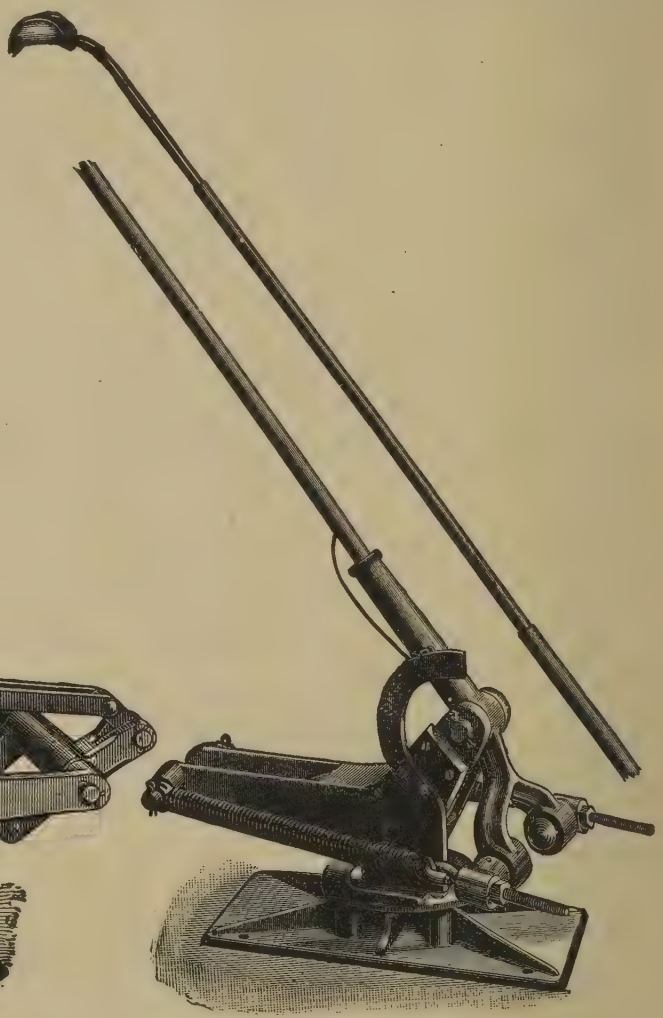


FIG. 71.—TROLLEY POLE AND STAND WITH SLIDING CONTACT.

This reaction of counter force generated in the motor is also utilized as an automatic regulator of the motor, for, as stated above, this counter force depends upon the field and the speed of the armature; therefore, it follows that if the field magnet is under proper control this counter force is also under control and can be made greater or less in relation to the driving force, and, consequently, the motor can be made to do whatever work is required of it.

"parallel" systems, but the latter has come into universal use.

In the series system, two overhead wires are required and all the current of the circuit is sent through the first motor, then on to the second, and through this to the third, and so on to the end; but in the parallel system only a portion of the current is sent through each motor.

These terms "series" and "parallel" will be better understood by reference to a familiar figure. Let

a dozen people take hold of hands and be placed in an electric circuit, the person on the right hand and on the left each holding an end of the wire in his free hand; now, it is evident that all of the current must pass through the arms and hands of each person, and they are said to be arranged in "series." Now, let the parties stand in line one behind the other facing in the same direction, and let each take hold of the positive wire of the circuit with the right hand and hold the negative wire with the left hand; it is evident that only a part of the current will pass through each person, and they are said to be arranged in "parallel."

A type of motor which has been extensively adopted is illustrated in Fig. 78 and is manufactured by the Edison General Electric Co., of New York. A fully equipped truck for this type of motor is shown in Fig. 79. The peculiarity of this motor consists in the method of regulation which is accomplished with the use of very little resisting medium, by the peculiar winding of the field magnets, and will be understood by the study of Fig. 80 which represents a detached field, and by studying Fig. 81 which also illustrates the wiring of a car and shows how the current is conducted from the trolley through the switches to the motor or lamps, and, by means of the wheels, to the rails.

It will be noted by reference to Fig. 80 that each of the field magnets is wound with three separate coils. This provides for governing the motor by the method known as "commutated fields." In starting the motor these three coils are placed in series with each other; this will be better understood by reference to Fig. 82; that is, the switch operated from the platform is so placed that all the current goes through the first coil, then through the second, then through the third to the armature. This gives, with comparatively small current, a very strong field and comparatively high resistance. When fields are arranged in this way, the energy, it is claimed, is not a dead waste, as is the case where resisting media are introduced, for a considerable portion of this energy goes to magnetize the field magnets, and by this means increases the starting effort of the motor. In the second position, Fig. 82, one of the coils is cut out. This gives a resistance of about two-thirds of the first arrangement, and with a given current has a somewhat less magnetizing force. In the third arrangement, two of the three coils are in parallel and in series with the third. By this arrangement the current splits between two coils so that each gets approximately one-half of it, then enters the third coil and thence through the armature.

This gives, approximately, half of the resistance

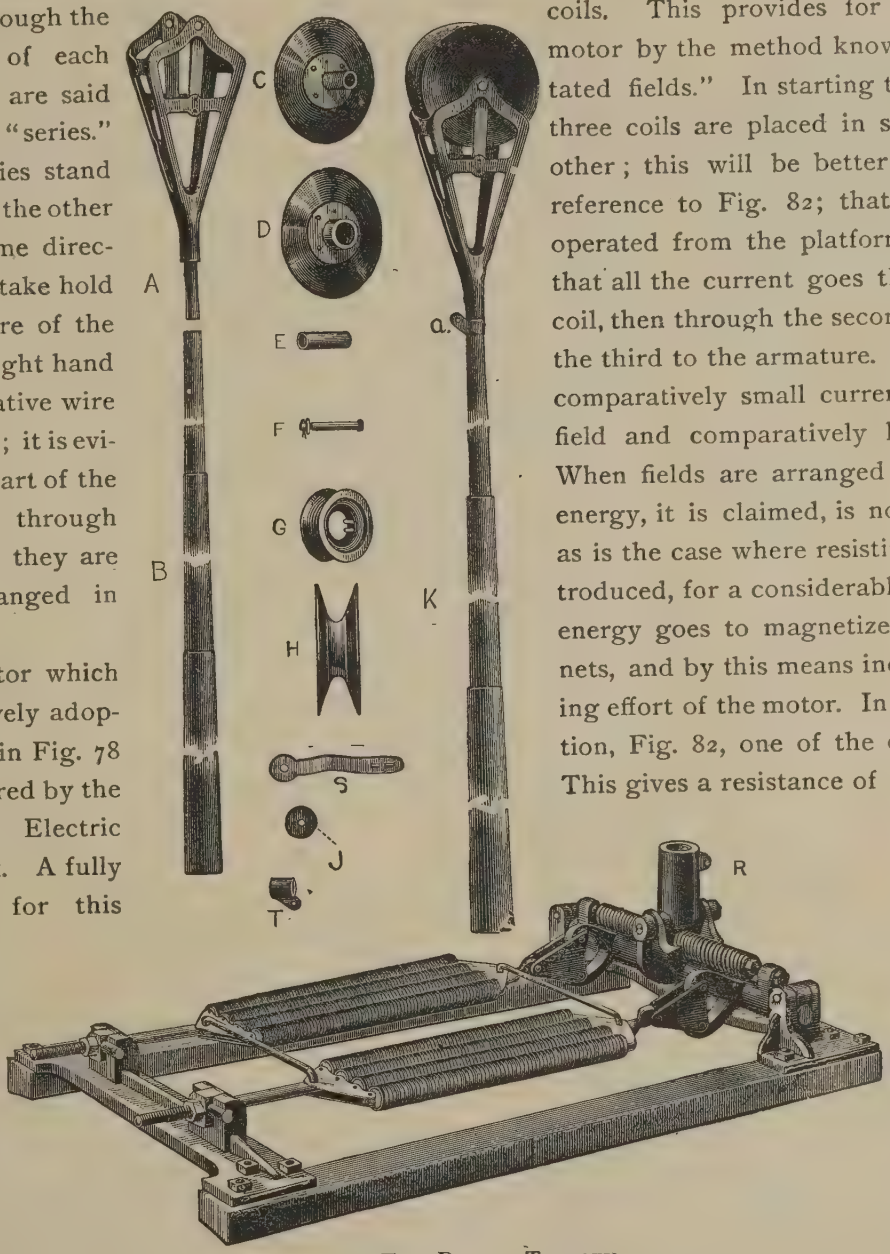


FIG. 73.—THE BOSTON TROLLEY.

K—Pole complete with wheel.
H—Wheel complete, with bushing.
C D—Flanges for wheel.
J—Contact washer.
R—Base complete with springs.
A—Frame for holding wheel.
F—Spindle for wheel.
E—Raw hide bushing for wheel.
S—Contact springs or brushes.
G—Contact ring for wheel.

of the first position. The fourth arrangement cuts out this single coil so that the current divides between two coils. This position gives comparatively small resistance, so that with moderately heavy loads the heat waste in the magnet is small. In the fifth position the three coils are placed in multiple arc; that is, the current divides between all three, each coil taking its own part. This gives a low resistance, and is suitable for working under heavy loads. The resistance in this position is about one-tenth that in the first position.

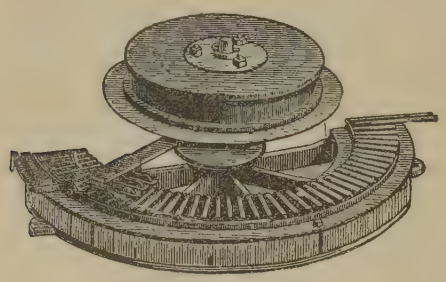


Fig. 74.—Rheostat.

It will thus be seen that the first position enables the motor to work with a small load but with a strong field, and the last position enables it to work under a very heavy load with a field of equal strength and with no greater heat waste than in the first position. The intermediate positions are used for moderate loads.

It may be noted that the combination of these coils can be varied to give any speed with a given load. That is, suppose there is a given load in the first position. In order to increase the speed it will be necessary to increase the electro-motive force at the armature, and this can be done by turning the switch in such a position as will put the magnets in multiple arc. This makes the drop in the magnet smaller, but gives a corresponding increase of speed.

Fig. 83 illustrates another type of double reduction motor, which is manufactured by the same company as above, but which is stronger and better, in many respects, than that just described. These motors are generally used two in series, and by this arrangement they are self equalizing and do not require equalizing coils, as the former type does, and being subject to a low pressure only are not liable to burn-outs. In several other points this motor is an improvement over the former; for instance, in the armature bearings, lubricating appliances and method of attaching the brush holders.

Fig. 81 is a conventional diagram showing the number and the relation of the wires to the switch and motor. The switch stand proper consists of a cylinder made of hard wood, having copper castings of peculiar shape attached to it, and so arranged that when the cylinder is rotated these copper forms are brought in proper contact with studs connected to the different wires. These cylinders are housed in against the dash on both platforms and are so connected that the motion of the car is controlled from either end.

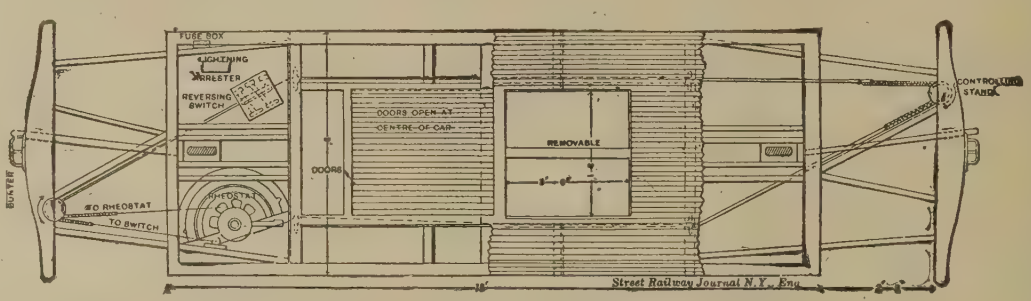


Fig. 75.—Car Platform with Electrical Equipment.

A motor employing an armature of the ring type is illustrated in Fig. 84. This is known as the Short motor, and was introduced by the Short Electric Railway Co., of Cleveland, O. In this particular motor four field magnets, *a b c d*, are employed, which are wound in series and are so mounted that their poles, which are crescent shaped, are presented to the sides of the armature instead of being placed outside the circumference, as is usually the case. The diameter of this armature being larger than the drum type of armature usually employed, the armature necessarily does not revolve as fast as

Fig. 76.—Sheet Iron Resistance.

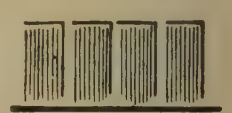


Fig. 77.—Section of Rheostat.

the latter, 1,000 revolutions per minute being the maximum.

This motor is regulated by a resisting medium

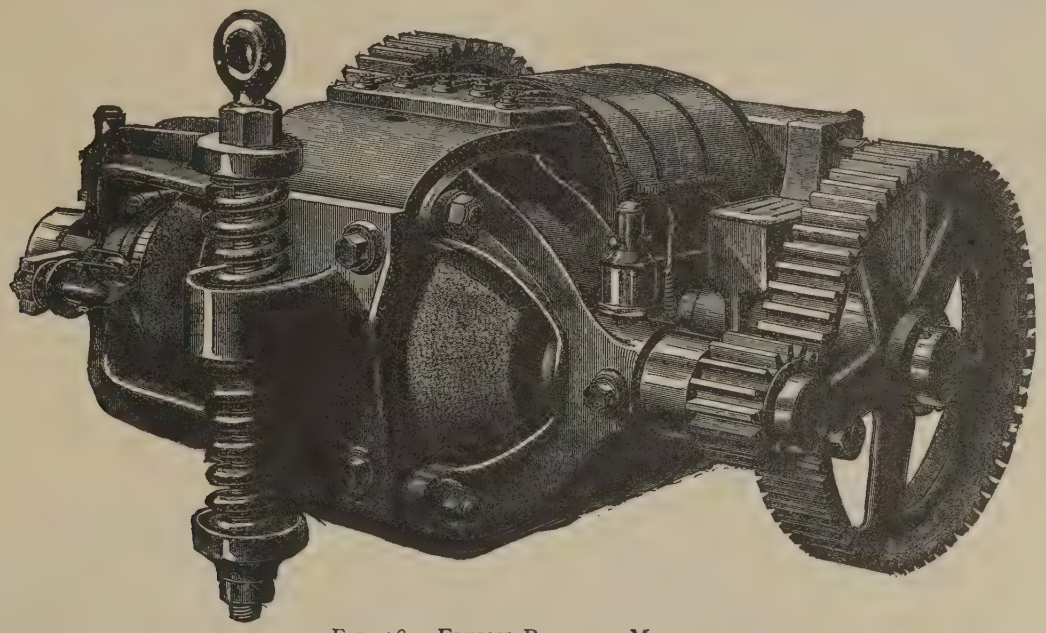


FIG. 78.—EDISON RAILWAY MOTOR.

or rheostat of a type somewhat different from that previously described, but employs the same principles. Still other peculiar features may be noted in its construction. The frame is cast in two parts which are joined together by means of wooden blocks, *x y*, which fit into sockets in each part of the frame, where they are properly bolted. The wooden blocks render the frame particularly rigid and serve to insulate the motor proper from the car axle. Wooden web gear wheels are also employed which render the operation of the motor noiseless and also assist in the insulation. A com-

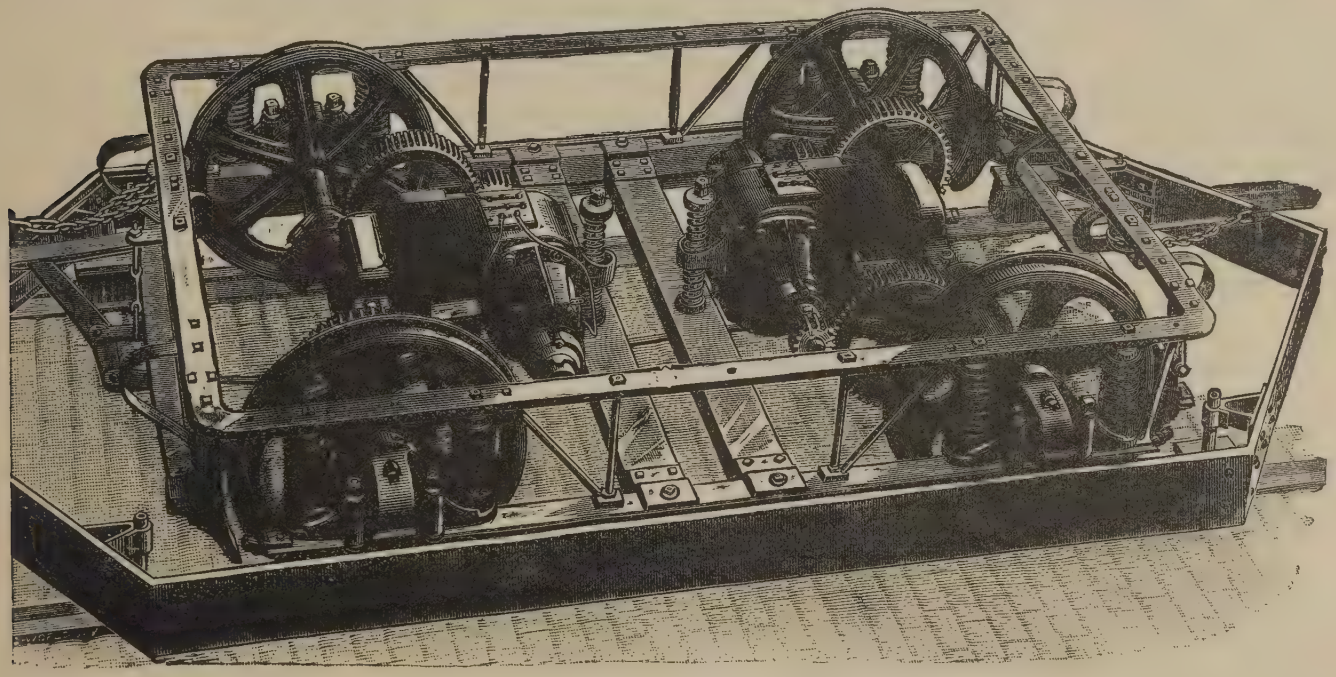


FIG. 79.—TRUCK EQUIPPED WITH EDISON MOTORS.

plete truck equipped with this motor is shown in Fig. 85.

The general design of still another motor and

truck is shown in Fig. 86. It consists of a single powerful motor mounted on a frame independent of the truck frame from which it is insulated by wood strips and by having the armature pinion built up of gun metal and fibre. The power is transmitted to both axles by means

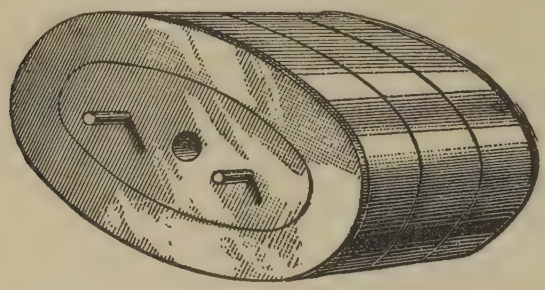


FIG. 80.—DETACHED FIELD OF EDISON MOTOR.

of a countershaft and bevelled gears, the latter being of the "shrouded" pattern, thus securing the maximum amount of traction. The fields are of wrought iron and the armature is of the ring type, but is so wound that the terminal wires connecting with the commutator are brought on top of the armature, thus simplifying commutator repairs. The tendency to heat and burn out is reduced to a low point by a peculiar arrangement from which the name "heat proof" motor, which has been given it by the manufacturers, the Detroit Electrical Works, is derived.

We come now to describe a radical departure in the method of mounting the motor on the truck and in the method of gearing.

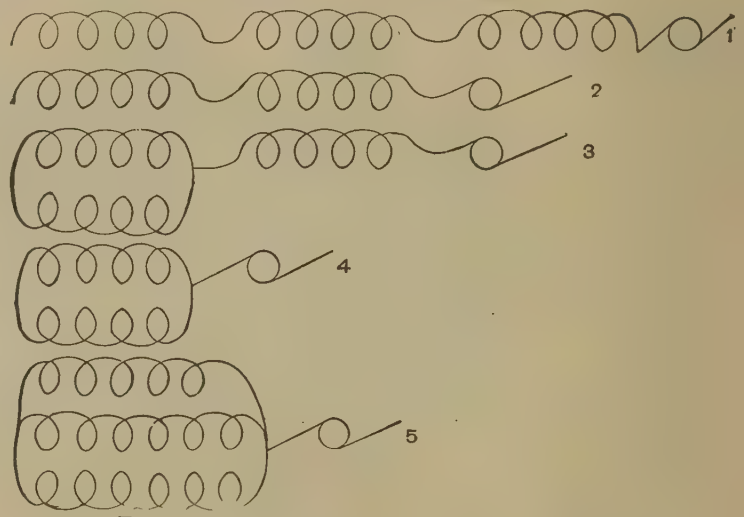


FIG. 82.—COMMUTED FIELD OF EDISON MOTOR.

Fig. 87 illustrates a type of single reduction gear motor manufactured by the Thomson-Houston Electric Co., of Boston. It is nearly iron clad, having two internal pole pieces carrying the field spools which partially surround the armature. The armature is of the ring type and the bobbins are wound close together around a smooth rim, no chambers being milled out for receiving the wires. The different parts of the motor are shown in Fig. 88. The

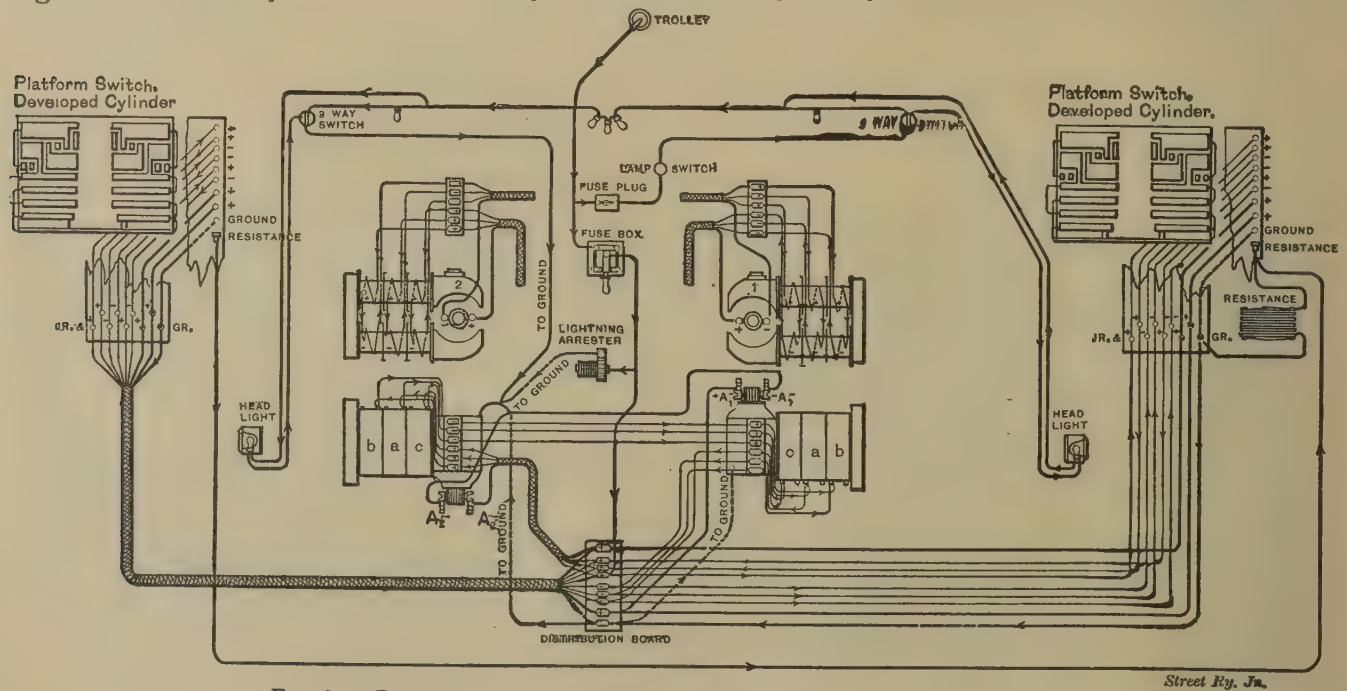


FIG. 81.—DIAGRAM SHOWING EDISON METHOD OF WIRING ELECTRIC CARS.

gears are enclosed in dust tight and oil tight cases provided with hand holes with spring covers through which lubricants may be introduced. The bottom and sides of the motor are protected from dust, snow and water by a sheet iron pan illustrated in Fig. 89. The reduction of speed between the armature and the car axle is about 4.8 to 1, so that when the car is running at the rate of even ten miles per hour the armature makes only about 538 revolutions per minute. By this arrangement of gear the operation is practically noiseless and the item of gear repairs is greatly reduced.

iron plates so that the completed core has slots to receive the wiring, and the wires are completely imbedded below the surface. The speed of the armature is comparatively slow, as the wires move only about 1,250 ft. while the cars pass over 1,000 ft., which is about one-fourth the velocity of the armature in the high speed type of motors. The field castings are hinged and can be readily swung back, giving access to the fields and the armature. (Fig. 92). The ratio of gear reduction is only 3.3 to 1. The gears are encased in cast iron housings partially filled with oil.

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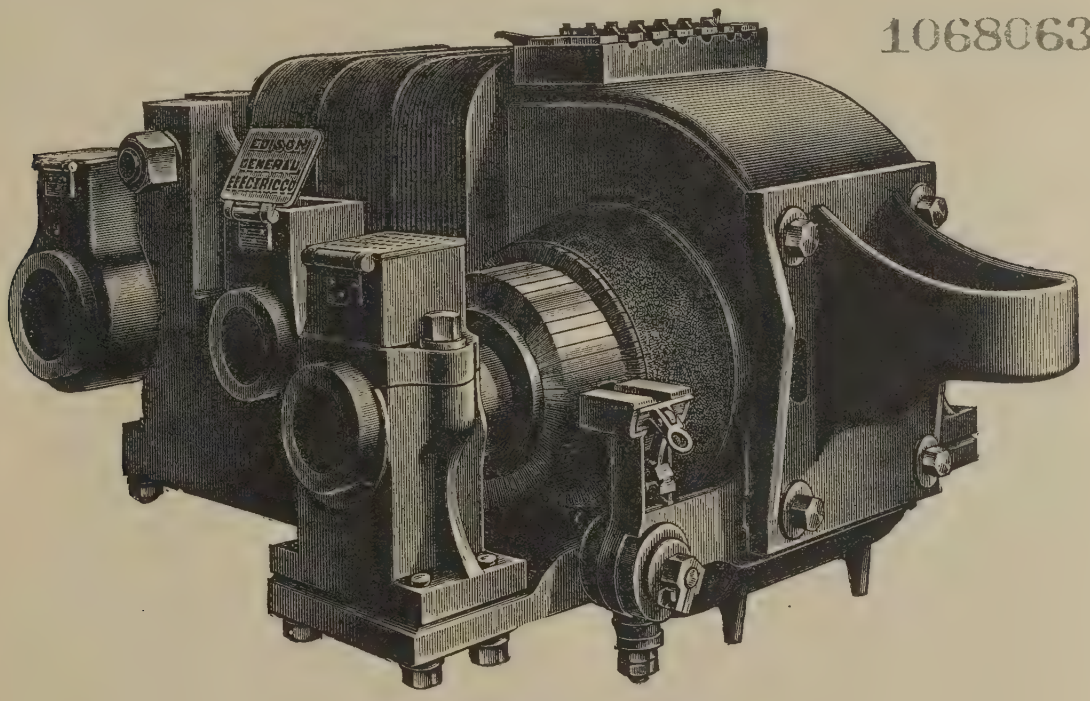


FIG. 83.—IMPROVED EDISON MOTOR.

Another single reduction motor is illustrated by Fig. 90, this particular type being manufactured by the Westinghouse Electric & Manufacturing Co., of Pittsburgh, Pa. By reference to the figure it will be seen that the general form of the motor is cylindrical, and it is of the multipolar type, there being four poles, which gives an advantage, it is claimed, over two pole machines in the line of slow speed, greater simplicity and, most important of all, greater heat radiating surface for the field coils and reduction of loss from the radiation of the lines of force. (Fig. 91). The armature is of the drum type and the core is built up of laminated, grooved

Another multipolar type of motor is shown in Fig. 93. This is known as the Baxter motor, and is manufactured by the Baxter Electric Motor Co. of Baltimore. The fields are formed in a peculiar shape, as will be seen from Fig. 94, and although there are eight poles they are placed in such a position that the vertical diameter of the motor is only a trifle greater than the armature. The armature is of the ring type and is about eighteen inches in diameter. The armature shaft carries pinions at both ends, four and a half inches in diameter, which mesh into split gears eighteen inches in diameter, keyed to the car axle. The motor is

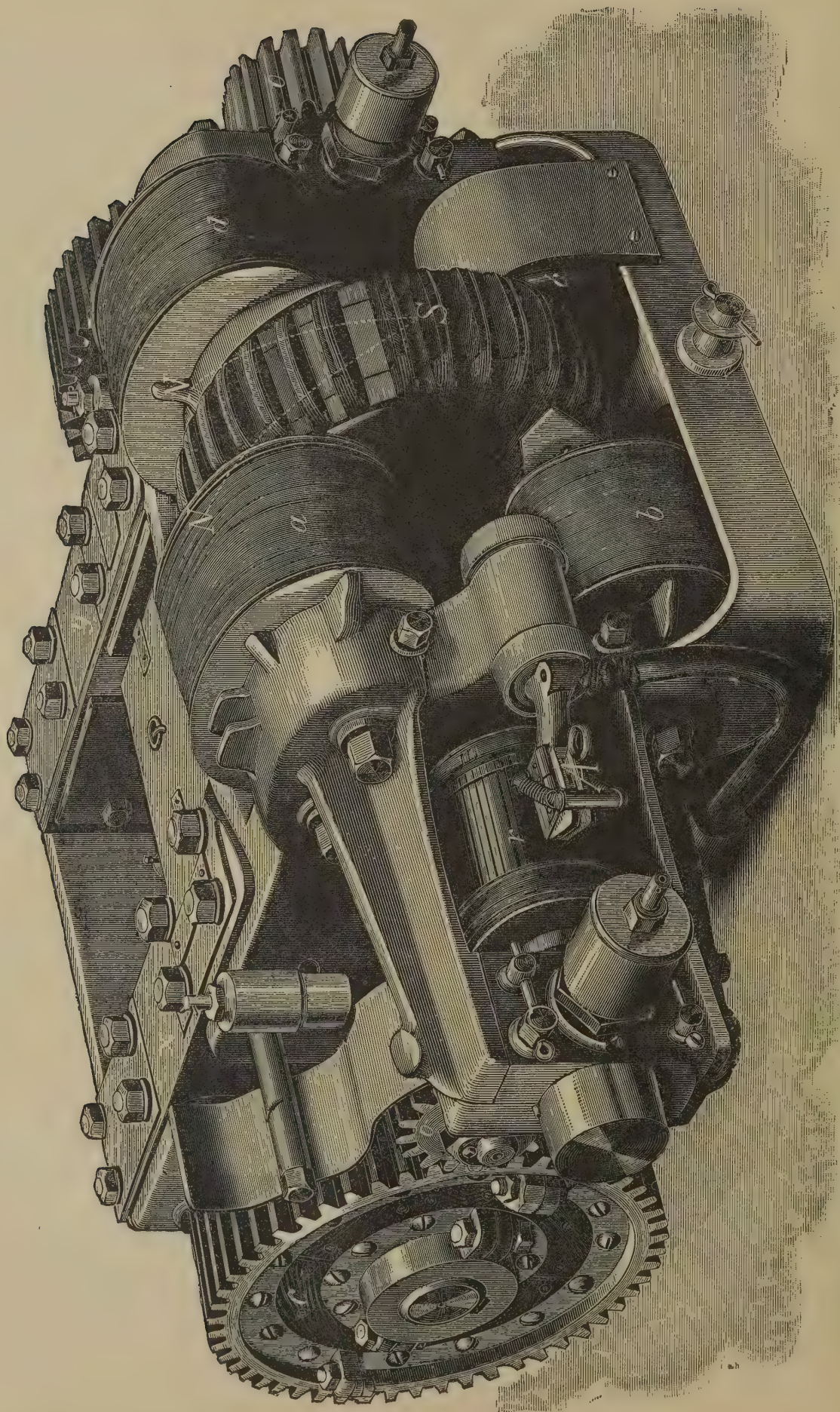


FIG. 84.—SHORT ELECTRIC RAILWAY COMPANY'S STANDARD MOTOR.

regulated by a rheostat of a peculiar type, consisting of numerous spools of sheet iron wound like a roll of ribbon. The gears are encased and run in oil. Fig. 95 shows a truck fully equipped for service with the above described motor.

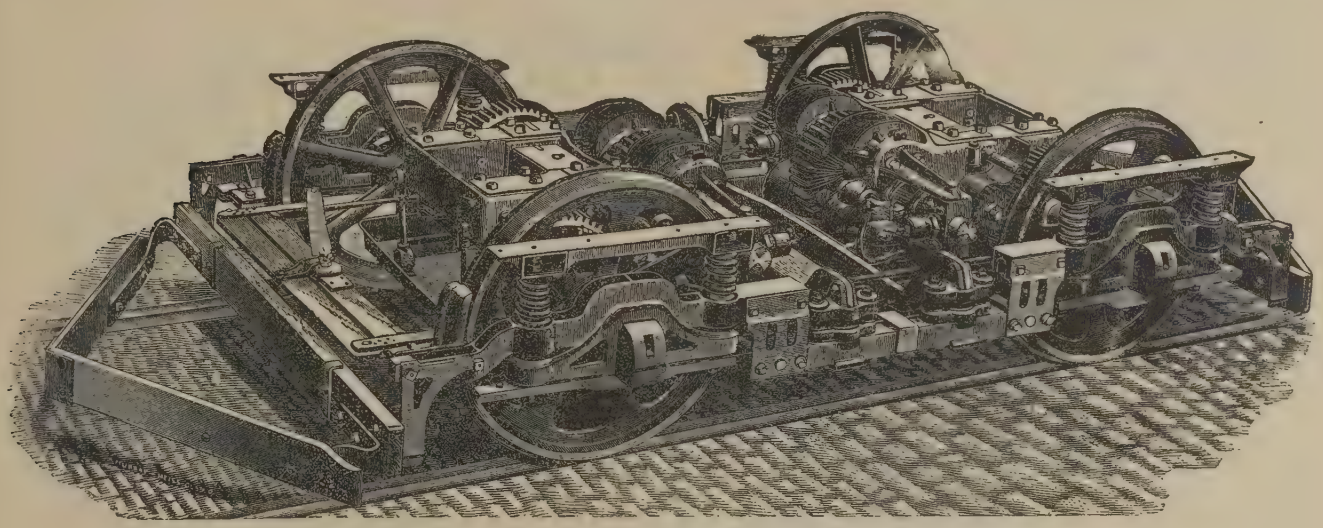


FIG. 85.—TRUCK EQUIPPED WITH THE SHORT "STANDARD" MOTORS.

by the Short Electric Railway Co., of Cleveland, O. The electrical features of this motor are essentially the same as those of the "Standard" motor manufactured by the same company, but, by a peculiar method of mounting, all gears are elimi-

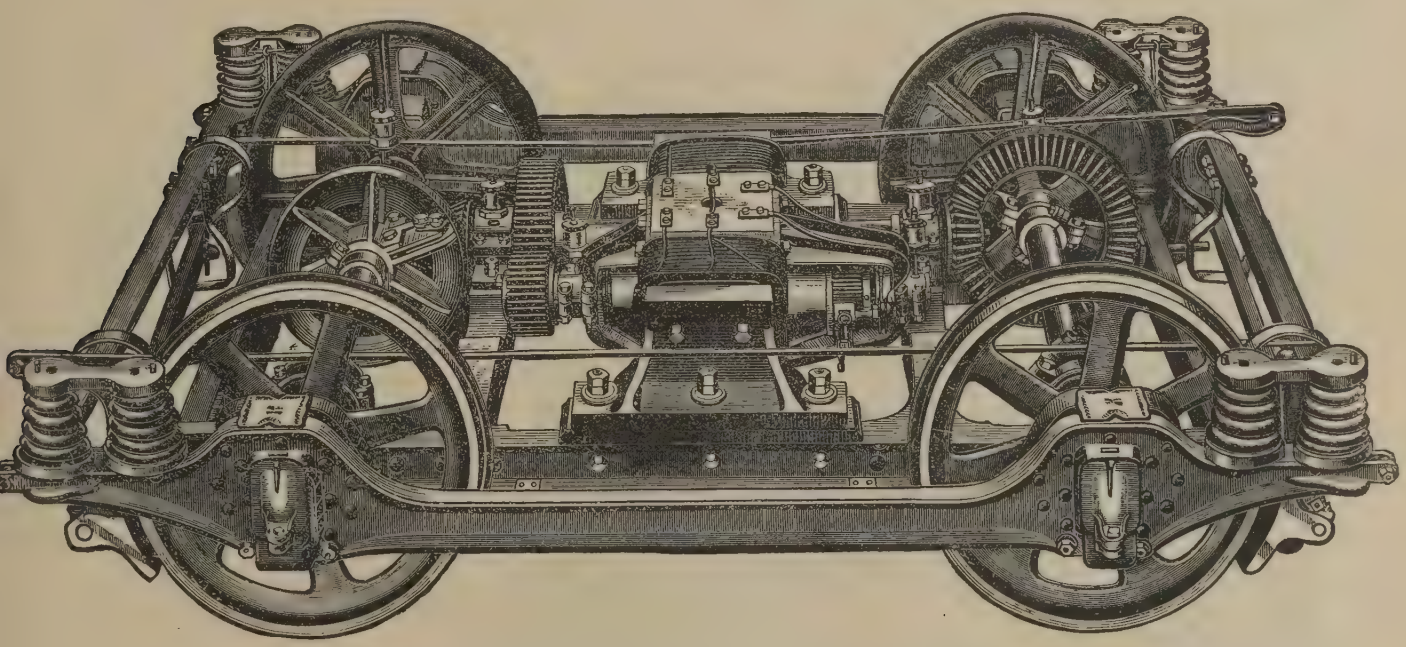


FIG. 86.—DETROIT ELECTRIC WORKS' MOTOR AND TRUCK.

A radical change from the types of motors previously described is shown in Figs. 96 and 97. This is known as the gearless motor and was introduced

nated and the speed of the armature is reduced to that of the car wheel, which is, usually, not more than 100 to 150 revolutions per minute.

By reference to Figs. 96 and 97, it will be seen that the armature and commutator are mounted on a hollow steel shaft, which surrounds the axle of the car wheel. The brushes in the eight pole machine are placed ninety degrees apart. The hollow shaft being larger than the axle, there is left an air space of an inch or more between the axle and the inside of the shaft. The journal bearings of the armature shaft are formed in casings, to the sides of which the field magnets are bolted. The casings are supported by cast iron truck frame. A three armed casting called a "spider" is keyed to the hollow armature shaft just outside the bearings, by means of which power is transmitted to the car wheels, the arms of the spider being provided at their ends with rubber cushions which rest against lugs cast in the face of the car wheels. The power is transmitted without shock or jar, and the wheels turn in the same direction as the armature.

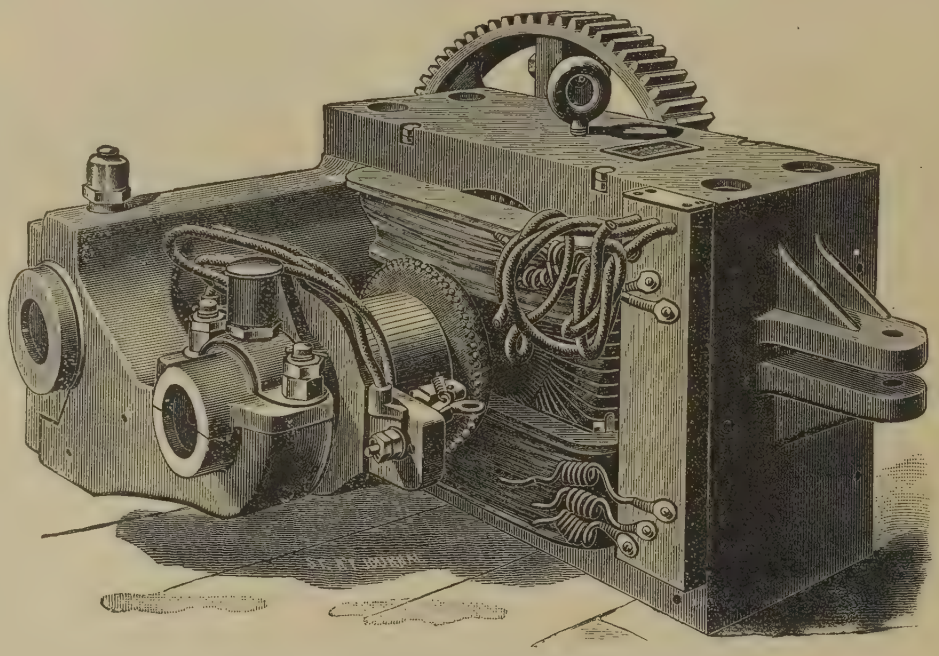


FIG. 87.—THOMSON-HOUSTON S. R. G. MOTOR.

The motors are so mounted that the opposite arms of peculiar shape, extending forward and backward, which at their ends are cushioned upon channel bars extending from side to side of the diagonal wheels drive in the same direction, so that the rubber cushions are constantly held in contact with the lugs of the car wheels and insure easy

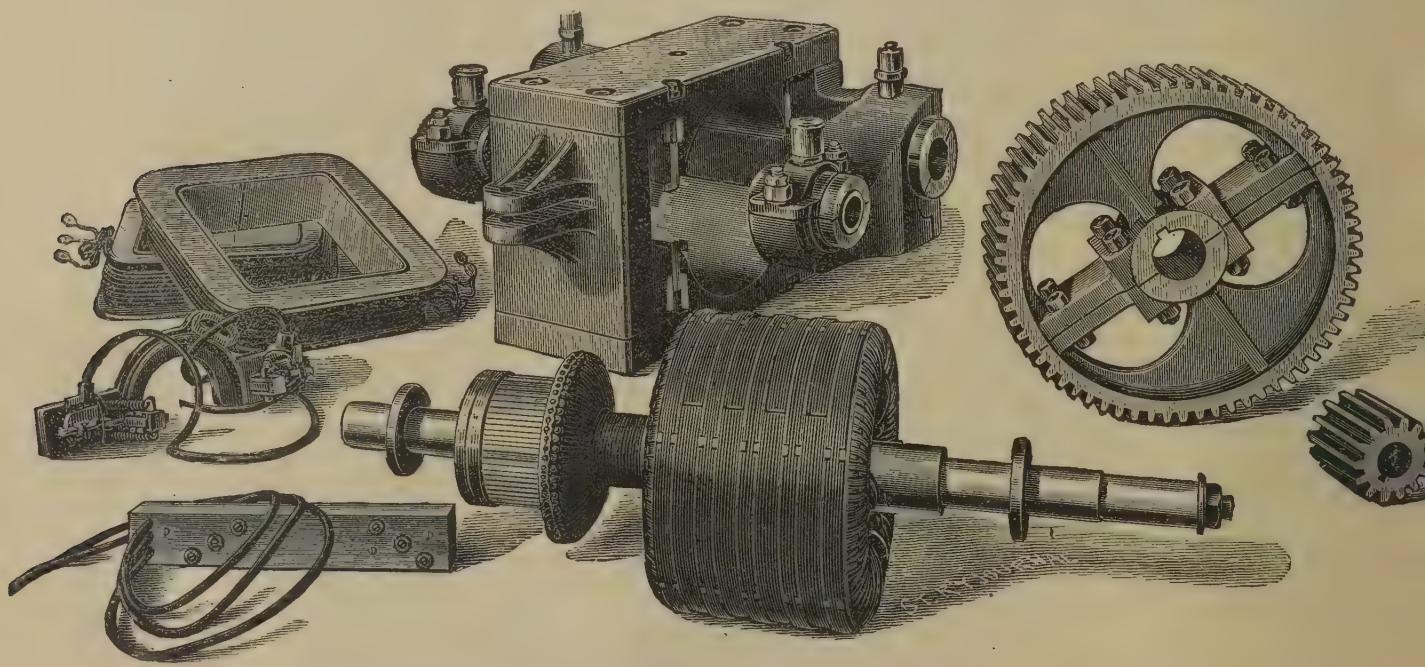


FIG. 88.—DISSECTED S. R. G. MOTOR.

starting in either direction. The construction of the casing admits of its being readily opened for inspection, and when necessary to make repairs the lower half may be removed, the car body jacked up, the armature and axle rolled out, and another equipment put in its place with the shortest possible delay. The bobbins, in case of a burn-out, can be re-wound in a few hours without taking the motor apart or off the car axle. (Fig. 99.)

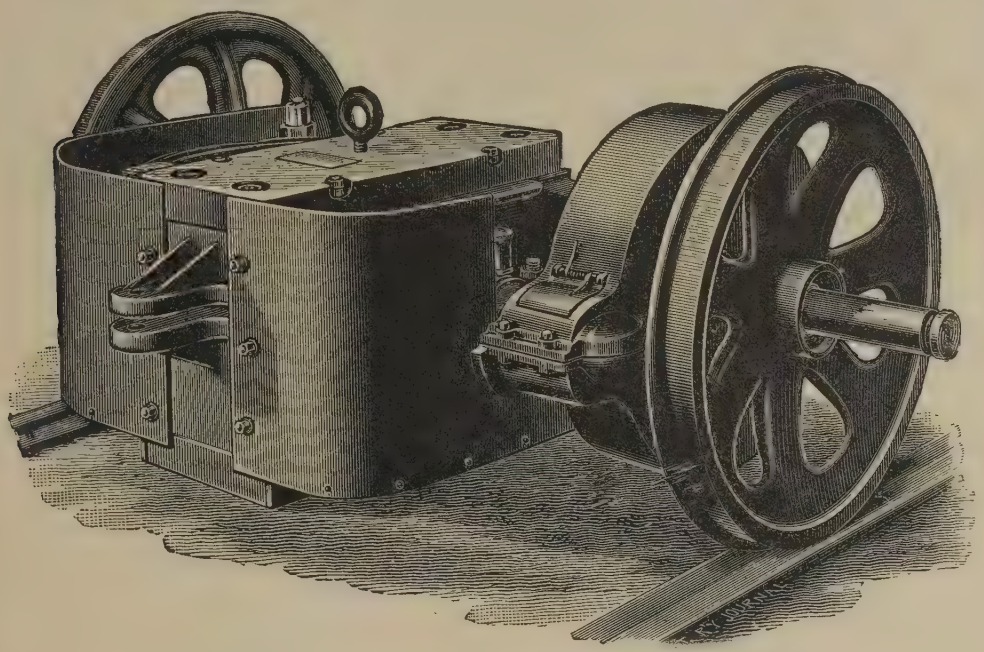


FIG. 89.—DUST PAN AND OIL TIGHT CASING OF S. R. G. MOTOR.

Some of the advantages claimed for this motor are as follows: In the method of mounting the weight of both motors is distributed over the entire truck, and no part of the weight is carried directly on the car axle. Being flexibly suspended, the motors can play up and down without coming in contact with the axle; hence, it is easier upon the rails and joints than when hung in the ordinary manner, and the crystallization of frames, axles and wheels is avoided. The absence of gears reduces to a minimum the power necessary to propel a loaded car, and eliminates the noise. The low speed also avoids the squealing of commutator brushes. The commercial efficiency of the motor is increased about twenty-five per cent. above that of the "Standard," and the cost for repairs and maintenance is reduced about seventy-five per cent. An improved single reduction motor for street car service worthy of mention is that made by the Edison General Electric Co., and illustrated in Figs. 100 and 101.

The motor, as will be seen, is of the iron clad type with two poles, and the frame, which is of cast iron, is constructed in two halves, which arrangement facilitates the removal of the armature for examination or repairs. The armature is of the Gramme ring type with Paccinotti teeth. The two field spools are each wound in three sections, and the speed is regulated by a commutation of the sections, an arrangement peculiar to the Edison system, and which has been previously described. Among other advantages, this arrangement provides that the car may be started with the lowest possible waste of power, as the initial torque in the armature is greatly increased, having a strong field due to the first commutation. The

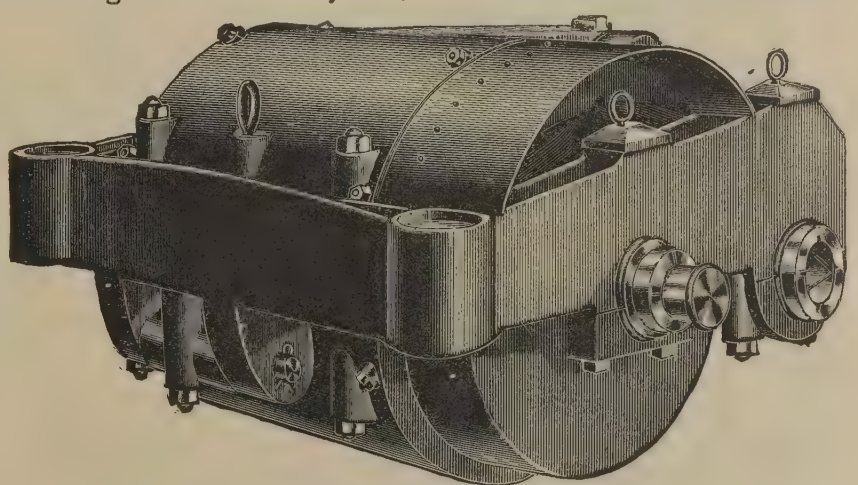


FIG. 90.—WESTINGHOUSE FOUR POLE MOTOR.

speed of the armature in the twenty H. P. motor is 440 revolutions per minute, and according to the gearing employed gives a heavily loaded car a speed of from eight to ten miles per hour. With an ordinary load the speed is from twelve and a half to eighteen miles.

The motors are manufactured in two sizes, rated at twenty and thirty H. P. Other sizes, suitable for narrow gauge roads and other peculiar conditions that are sometimes met with in street railway practice, are also made. The twenty H. P. size measures over all (along armature shaft) thirty-eight and a half inches, and weighs complete with gears, covers, etc., 1,950 lbs. The thirty H. P. motor, which is similar to the above, has an armature speed of 330 revolutions per minute, and measures over all forty-one and one-sixteenth inches, and weighs complete 2,800 lbs.

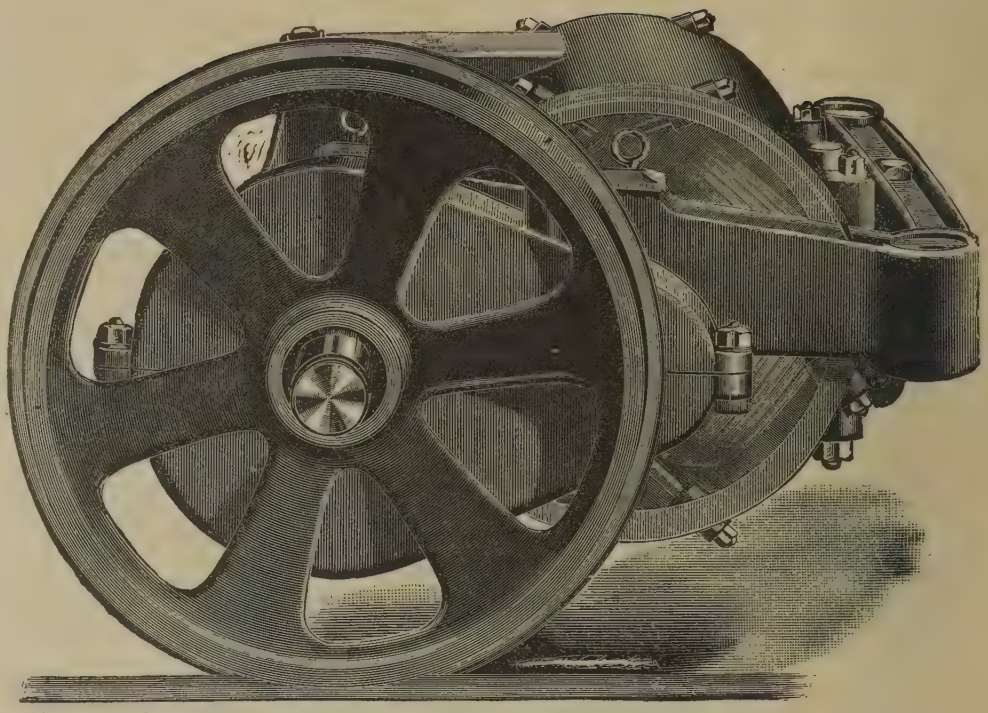


FIG. 91.—SIDE VIEW OF WESTINGHOUSE MOTOR AND TRANSPARENT VIEW OF FIELDS

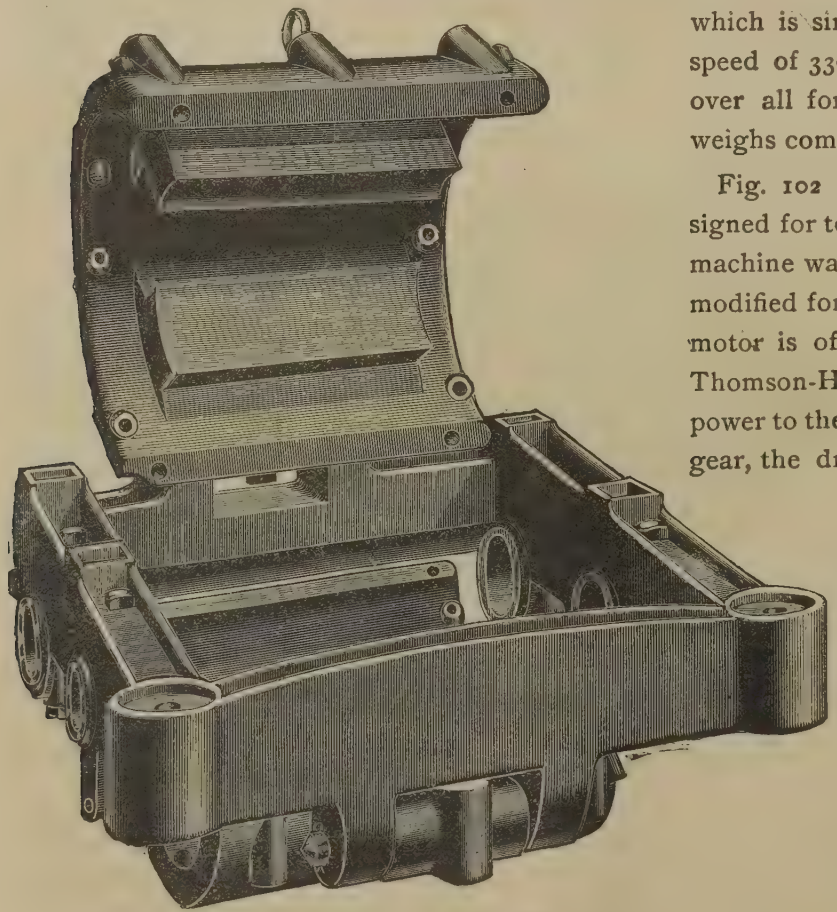


FIG. 92.—FRAMING AND FIELD CASTINGS—WESTINGHOUSE MOTOR.

Fig. 102 illustrates an electric locomotive designed for towing one or more cars. This particular machine was designed for freight service, but, in a modified form, is adapted to street car work. The motor is of the "C" type, manufactured by the Thomson-Houston Electric Co., and transmits its power to the rear axle by means of double reduction gear, the drivers being coupled by parallel rods. The pinions are of aluminum bronze and the gears of wrought metal, and run in oil tight casings. Two rheostats are employed, and so arranged that no reversing switch is required. The motor is thoroughly waterproof, the fields being enclosed in canvas cases coated with mineral paint. The object of using an electric locomotive is to save the expense of providing an electrical equipment for both open and closed cars.

STORAGE BATTERIES.

This term and that of accumulators or secondary batteries has been applied to a class of *chemical batteries* in which chemical action, primarily induced by the application of a current of electricity, supplied from a primary battery or from a dynamo, enables a strong current to be given back any time after cutting off the charging current. This derived current is the product of a certain chemical re-action taking place between the materials of which the battery is composed. In our previous study we have seen how an electric current is mechanically produced, transmitted and applied to the movement of the cars. We have now to learn about the chemical production of a current and how it is applied to the movement of cars by placing the batteries directly upon them, making a self contained motor car, which is a very desirable method of traction.

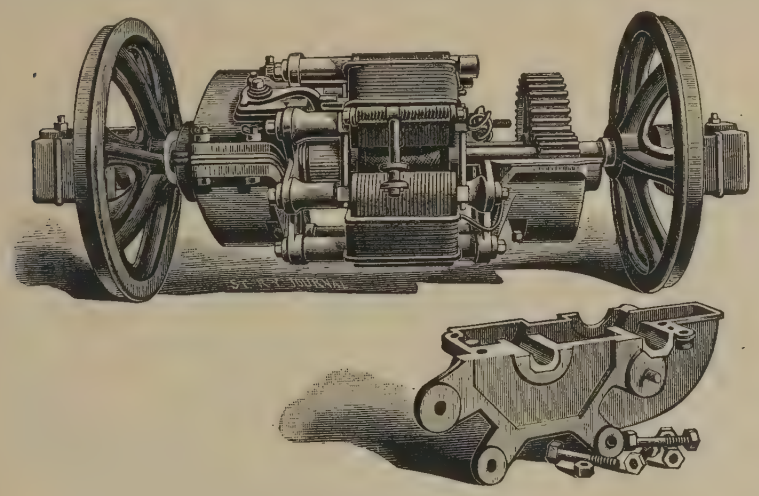


FIG. 93.—BAXTER MULTIPOLAR MOTOR.

In order to understand the action of storage batteries it will be necessary to study briefly the old time chemical battery.

As is well known, chemical batteries were the first sources of continuous electric currents, and of these the simplest form and best known are those in which a plate of zinc and a plate of copper are immersed in a vessel containing dilute sulphuric acid. Such an arrangement is called a galvanic cell or element. (Fig. 103.) The circuit is said to be closed when the wires attached to the plates touch each other, and open when the wires do not touch each other. When the circuit is closed a current of electricity flows through it. Apparently, the positive current flows, in the cell, from the zinc through the fluid to the copper, but out of the cell it flows from the copper to the zinc, thus completing the circuit. The current is produced by the consumption, or eating up, of the zinc by the acid, the copper plate being but slightly affected.

When several galvanic elements are connected together, in the manner shown in Fig. 104, they form a galvanic battery, and, as indicated by the arrows, the current from the first zinc passes through the first liquid to the copper of the first element and on to the zinc of the second element

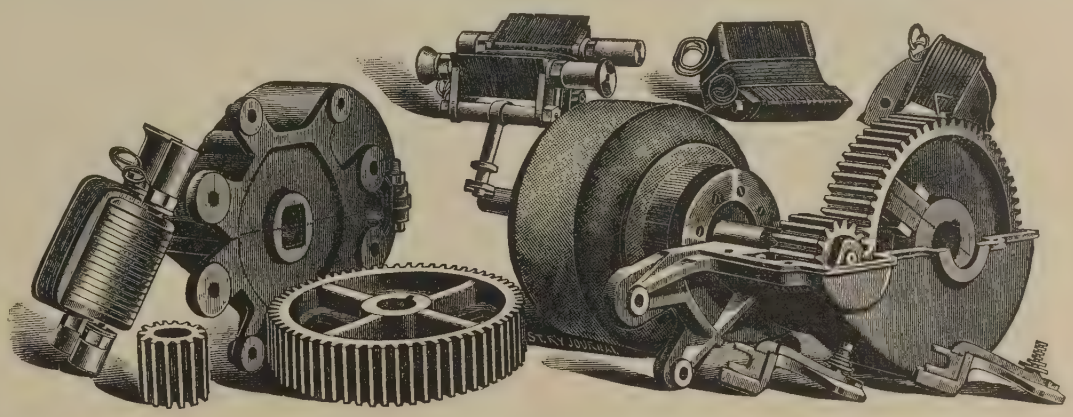


FIG. 94.—DISSECTED BAXTER MOTOR.

Then element No. 2 sends what it has received and its own on to No. 3, so that the pressure of current sent forward increases with the number of elements, and in the battery shown, where the elements are connected in series, it is fives times as great as it would be with only one element. Batteries consisting of two different metals and a liquid are not

very efficient, however, owing to the rapid decomposition of the liquid by the current, and because of the oxidization of the zinc, and also from the fact that the surface of the copper plate soon becomes covered with a layer of hydrogen gas, causing a current counter to that generated by the two metals and the liquid. To prevent rapid deterioration and to add to the life of the battery, various means have been proposed. One is the use of amalgamated zinc, or zinc covered with mercury. This prevents the too rapid oxidization of the metal; another is to form the element with an inner and an outer cell separated by a porous partition made of unglazed porous porcelain. The amalgamated zinc is placed in the outer cell containing dilute sulphuric acid, and the copper is in the inner cell containing a saturated solution of copper sulphate or blue vitriol, as illustrated in Fig. 105; or the relation may be reversed. With this construction the freed atoms of hydrogen do not collect on the copper plate, but pass through the pores of the porcelain cup and replace copper in the solution. The result is that pure copper instead of hydrogen is deposited on the copper plate. This type of primary battery is used extensively in telegraphy, also for call bells and signaling purposes, but is too expensive to be practically applied to power purposes.

Now, we have seen that the primary battery is formed by placing two dissimilar metals in a liquid and connecting them with a conductor outside of the liquid. If two pieces of the same metal be used no action will take place; but, strange as it may seem, a secondary battery is usually formed by using two plates of the same metal. The simplest storage cell for a secondary battery consists of two plates of lead immersed in dilute sulphuric acid, and chemical action is induced by causing an electric current from a dynamo to pass through the liquid from one lead plate to the other. This

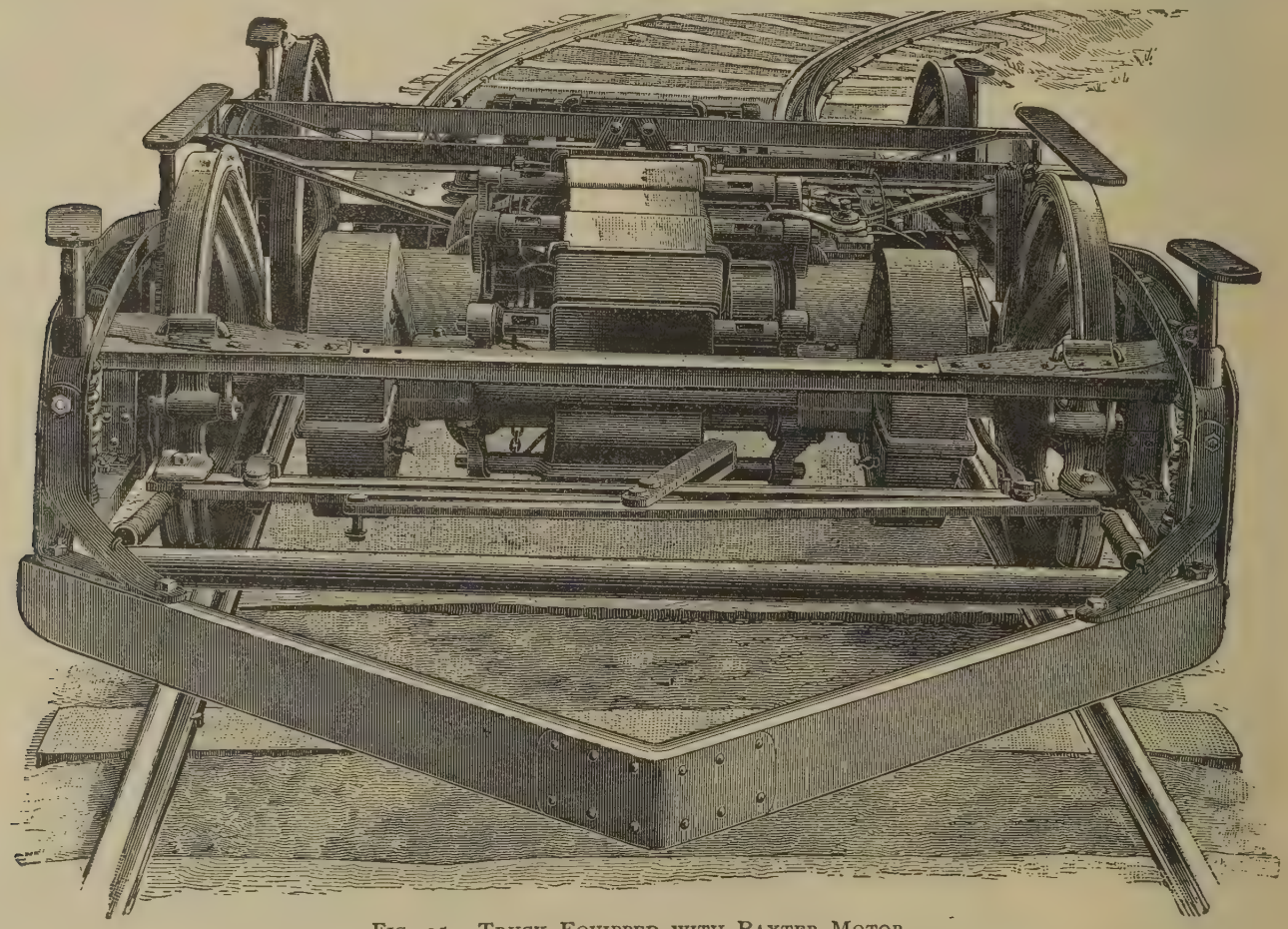


FIG. 95.—TRUCK EQUIPPED WITH BAXTER MOTOR.

application of the current to the cell is termed charging, and it effects the decomposition of the liquid, or electrolyte as it is called, and positive and negative radicals are deposited on the plates, or unite with them, so that, on the cessation of the charging current, there remains a cell capable of generating an electric current. If, now, the charged plates be connected with a conductor outside the liquid, a current is produced which flows through the liquid in the opposite direction to that of the charging current. On the passage of the charging current the positive plate is found to be covered with lead peroxide and the negative plate with finely divided spongy lead. To produce the discharging current the peroxide gives up its oxygen to the spongy lead; and after the discharge the active matter in both plates is found to contain lead sulphate. When this change is thoroughly effected the cell becomes inert and will furnish no further current until again charged by the passage of the current from some external source. In order to increase the capacity of the storage cells, and thus prolong the time of their discharge, the coating of lead sulphate left on each of the plates when neutral is made as great as possible. To effect this, two processes called *forming* the plates are employed; one consists in first charging the plates as already described, and then reversing the direction of the charging current. This is repeated until a considerable depth of the lead in the plates has been acted upon; but this process takes time, and in order to shorten the time for *forming*, another process has been resorted to which consists of covering the plates with red lead, and by this means their capacity is very much increased.

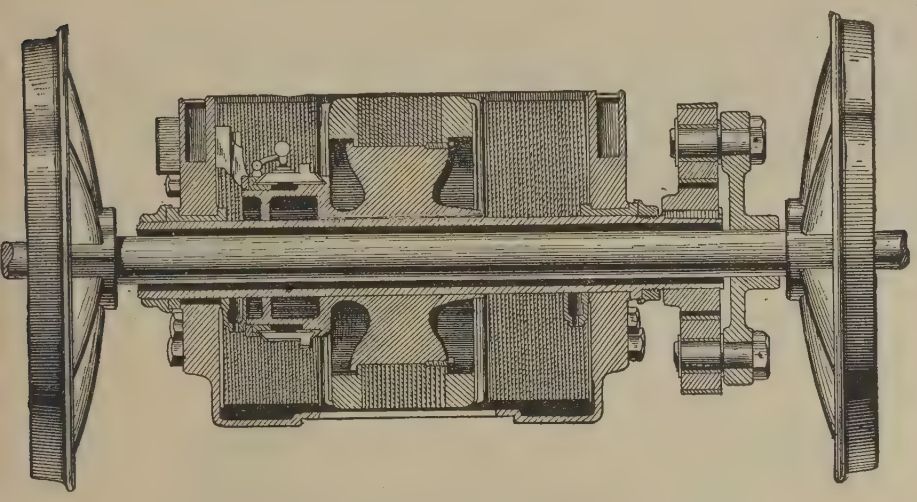


FIG. 96.—SECTION OF FOUR POLE (SHORT) GEARLESS MOTOR.

From the above it will be seen that a storage battery does not store electricity, but does store such materials as may be decomposed by the action of the charging current, and which will produce a current of their own on the removal of the charging current. A general distinction between primary and secondary batteries and that which gives value to the latter, lies in the fact that, in the former, the current is produced by the consumption of one or both of the elements composing the cell; while, in the latter, the elements retain their form as such, and merely pass from one state of combination to another.

Many electricians have made a study of this subject, and have endeavored to improve secondary batteries in different ways, the first object being to enlarge the surface of the two leaden plates; the second to so apply the red lead or active material to the plates that it shall not fall off; and the third to find some other metal that can be used instead of lead, in order to reduce the weight of the battery.

In one class of batteries the lead plates are in the form of a grid, and are simply thin castings of lead having a large number of holes in them, as shown in Fig. 106. The holes are made tapering from each surface to the centre of the plate, so that when the red lead, used in the form of a dry powder or paste, is pressed in, it becomes a plug and is not liable to fall out, even though it should contract slightly after a certain period of use.

The grids or plates are not necessarily lead castings, but are preferably made by machinery. Ma-

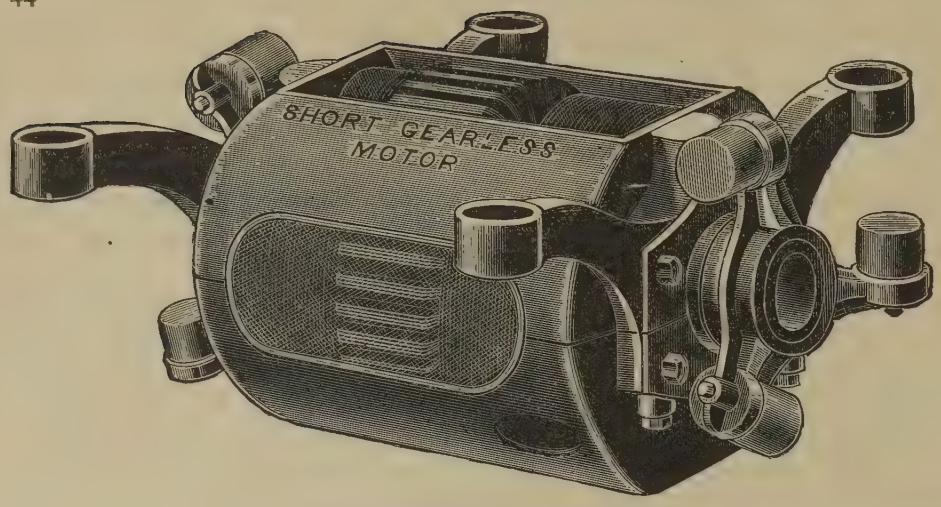


FIG. 97.—SHORT GEARLESS MOTOR.

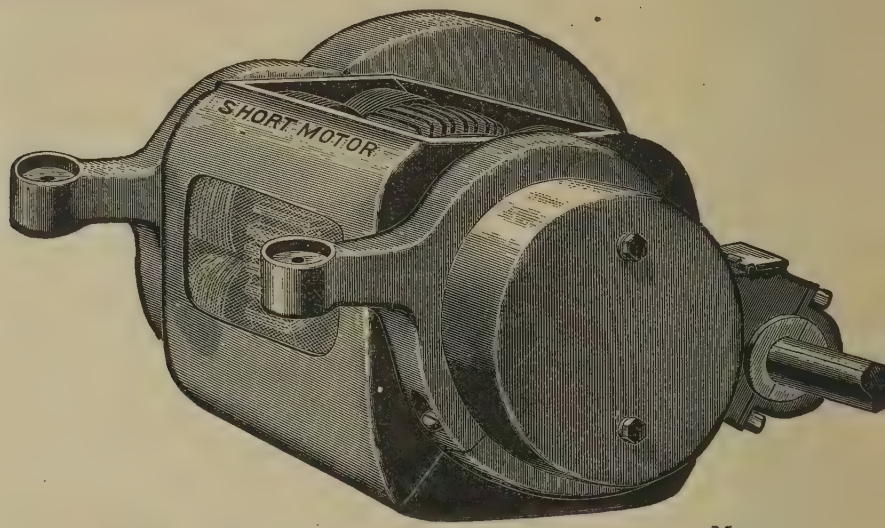


FIG 98.—SHORT "WATER TIGHT" SINGLE REDUCTION MOTOR.

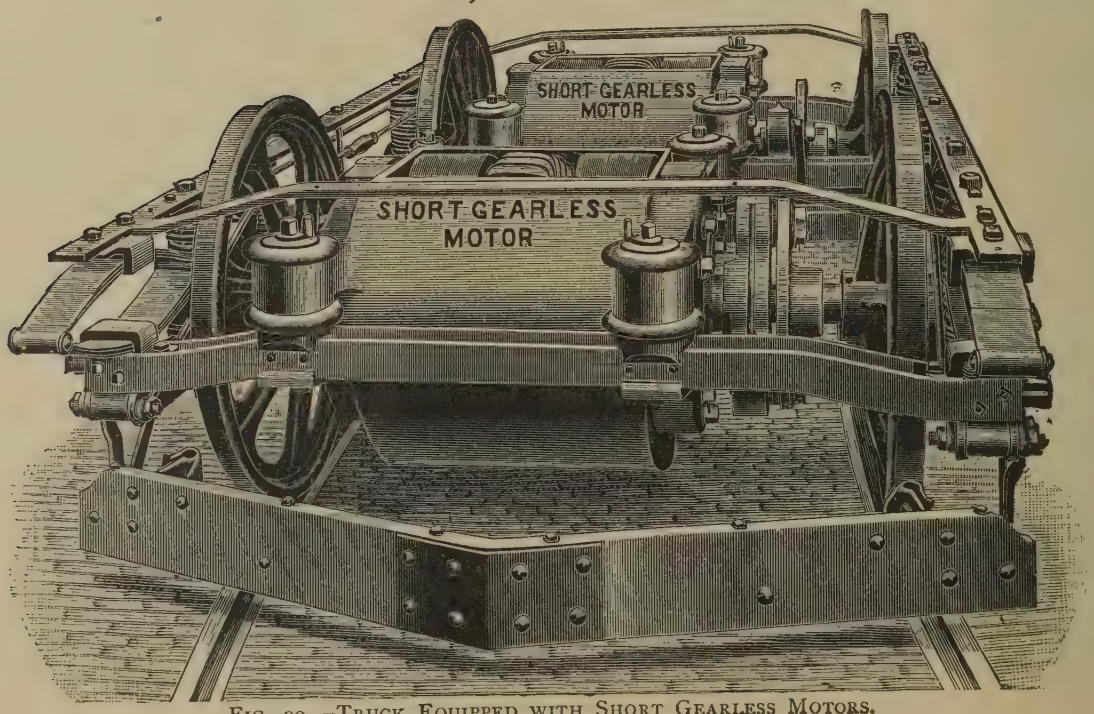


FIG. 99.—TRUCK EQUIPPED WITH SHORT GEARLESS MOTORS.

chines have been devised which press or stamp out the plates very rapidly, the metal first being heated till it becomes plastic and about the consistency of putty. The machine made grids are lighter, much more durable and less likely to contain blow holes than those formed by casting.

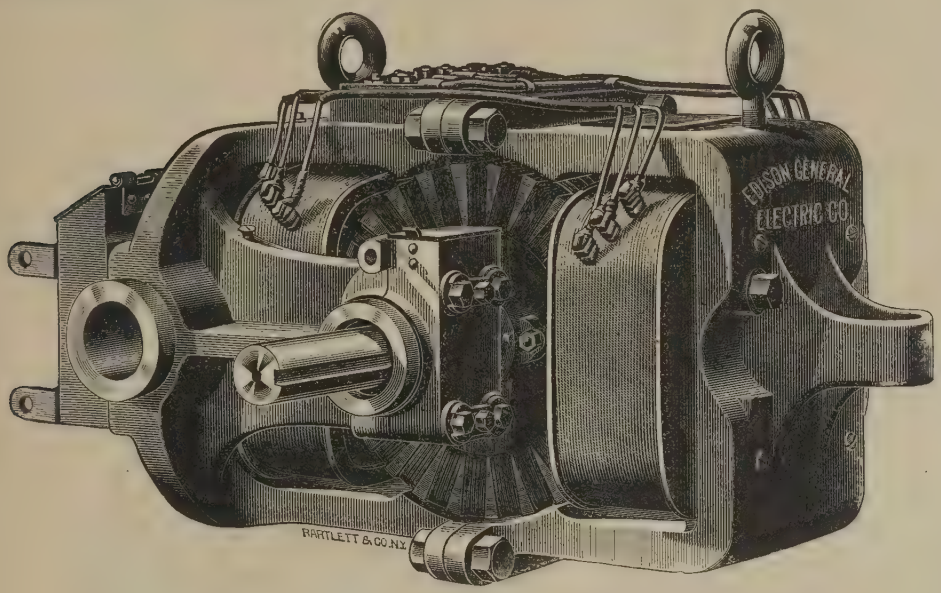


FIG. 100.—EDISON TWENTY H. P. IMPROVED SINGLE REDUCTION MOTOR.

In order to get as great a surface as possible in contact with the liquid or electrolyte, it is customary to arrange alternately in a glass cell or a case made of vulcanized rubber, a certain number of plates, placed close together without touching. For instance, there can be put together ten negative and nine positive plates in one cell, the plates being separated by rubber bands or strips of vulcanized rubber about an eighth of an inch thick. Such an arrangement of cell and plates is termed an element (Fig. 107) and when a number of elements are connected, either in series or parallel, they form a secondary battery.

Another form is shown in Fig. 108. In this particular system the grids are about six inches square and one-eighth of an inch thick, and are composed of an alloy of lead (ninety-five per cent.), antimony and mercury. The cavities of one plate are plugged with litharge and those of the other plate with minium, or red lead. This material is termed the active matter, and is applied mechanically to the grids, or supporting plates, which act simply as conductors. On being placed in the electrolyte, the litharge, by the action of the charging current, is converted into reduced or spongy lead and becomes a negative plate, and the red lead is converted into lead peroxide and becomes the positive plate of the completed element.

The positive plates are also made by pressing a number of sheets of lead-foil, covered with graphite, between two plates of sheet lead, which are then perforated and bound together with lead rivets placed about an inch apart (Fig. 109). The electrolyte is an acid solution of zinc sulphate, and the plates are rendered active by the process employed with plain

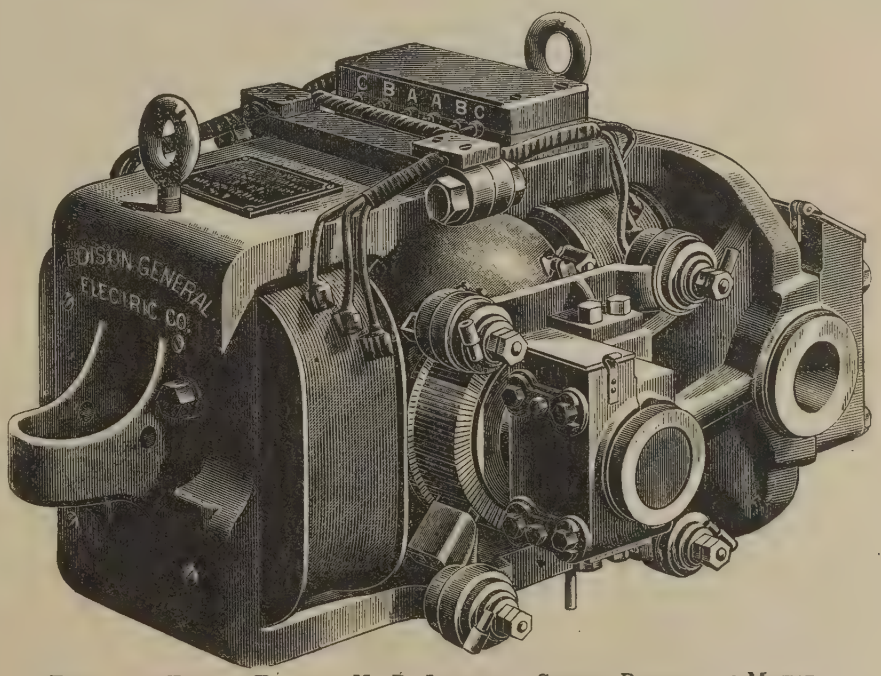


FIG. 101.—EDISON TWENTY H. P. IMPROVED SINGLE REDUCTION MOTOR.

lead plates. By this treatment the leadfoil is changed into an active material, and, from the construction, a very large surface is presented for the action of the acid. The negative plate, for use with the above, is made of zinc about an eighth of an inch thick and is perforated with large holes, as shown in Fig. 110. In the construction of the cell the zinc plate rests on a plate of copper, perforated to match the holes in the zinc plate, and all the plates are arranged horizontally, like shelves, one above the other. The copper plate acts only as a conductor, and the zinc plate, it is claimed, does not waste away, the chemical changes restoring it to its pure condition. It will be observed that each plate has a notch at one corner; this is to provide space for the conductor which connects all the plates of the same polarity in a cell together.

The operation of charging storage batteries from dynamos requires two to six hours. Care must be taken to have the batteries rightly "poled" with the dynamo, *i. e.*, to connect positive to positive and negative to negative poles. Otherwise the battery will continue to discharge instead of being charged. The same thing also occurs even when properly "poled," if the potential of the dynamo is allowed to fall below the total potential of the battery cells. When discharged to the proper limit, a lead storage battery has a potential of about 1.8 volts per cell. This is independent of the size or form of cells, which latter affect only the internal resistance of the cell. When fully charged the potential per cell may reach 2.15 volts, or as high as 2.4 volts should the circuit be suddenly broken. Hence, a battery of 100 cells would, when discharged, exert a counter potential of about 180 volts, and when fully charged about 215 volts, against the charging dynamo. The charging dynamo must always give a potential sufficient to overcome this back pressure or "counter electro-motive force," and besides, it must give enough additional potential to overcome all other resistances of the battery cells and connections.

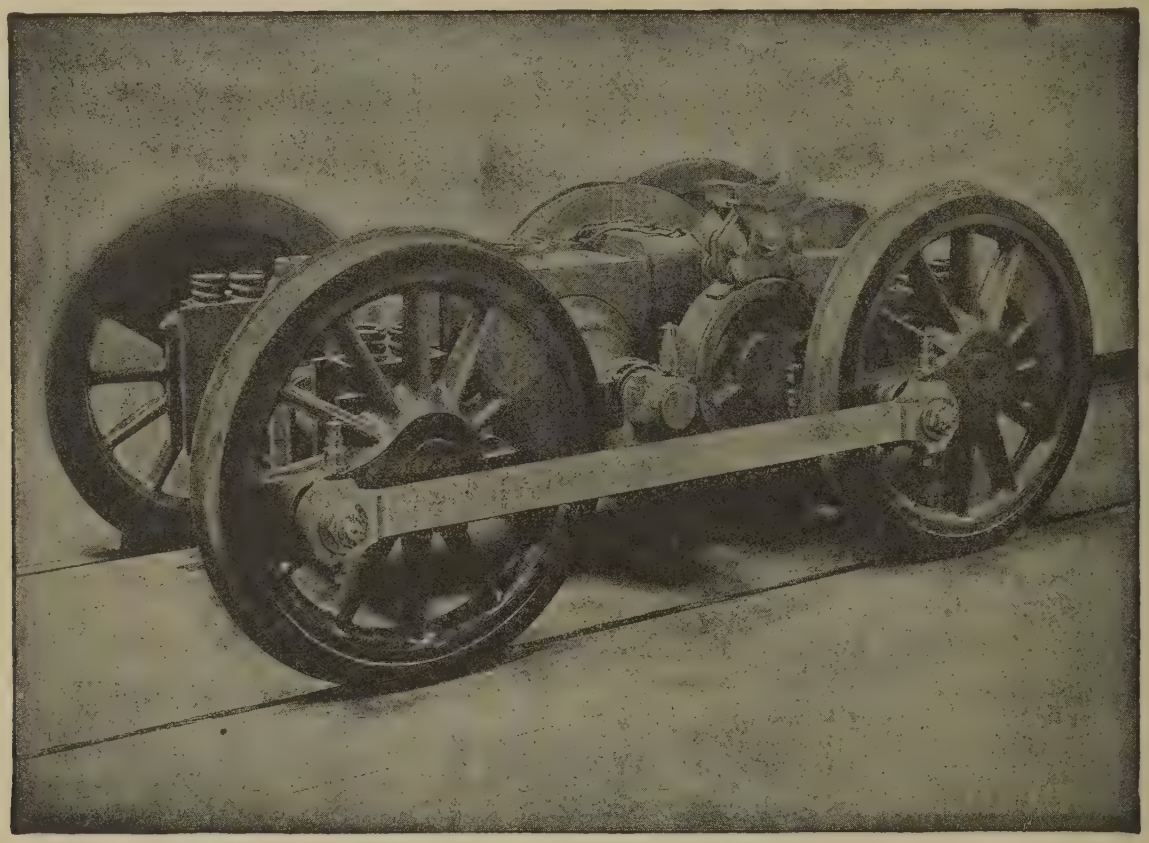


FIG. 102.—ELECTRIC LOCOMOTIVE TRUCK.

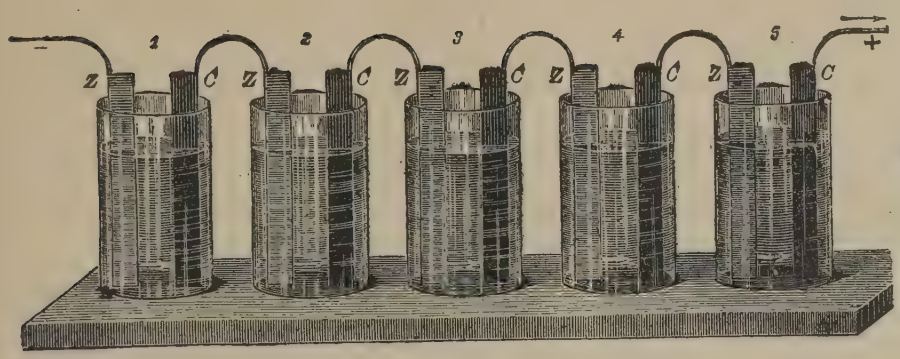


FIG. 104.—GALVANIC BATTERY.

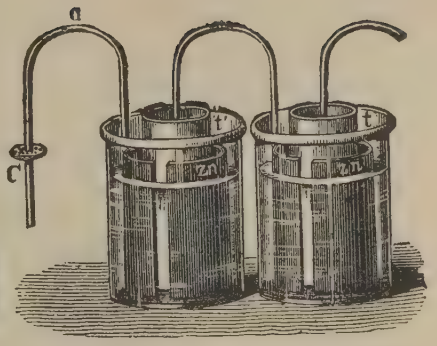


FIG. 105.—POROUS CUP—GALVANIC BATTERY.

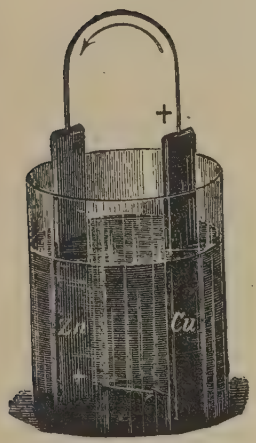


FIG. 103.—GALVANIC BATTERY.

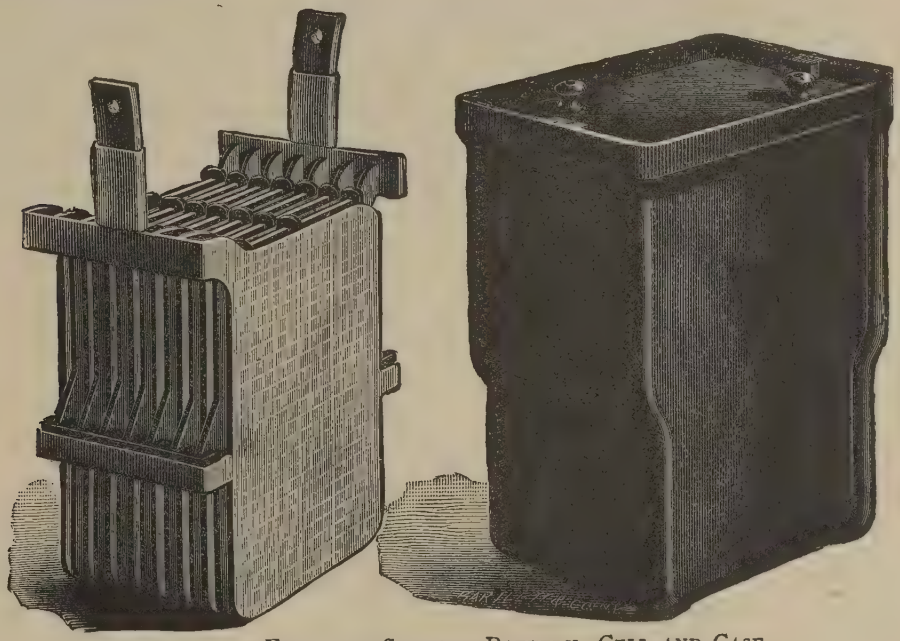


FIG. 107.—STORAGE BATTERY, CELL AND CASE.

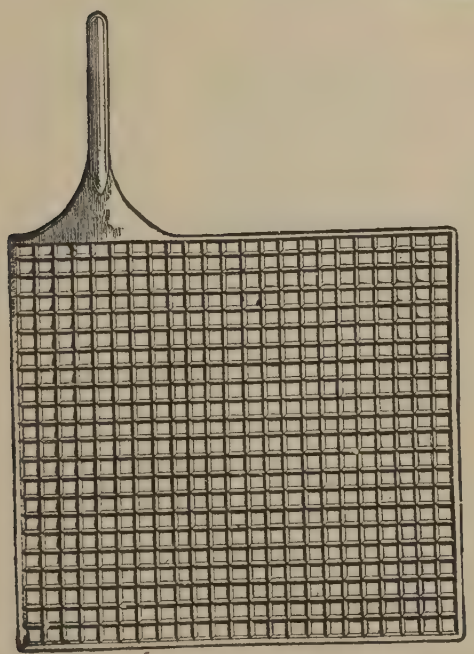


FIG. 106.—CAST GRID FOR STORAGE BATTERIES.

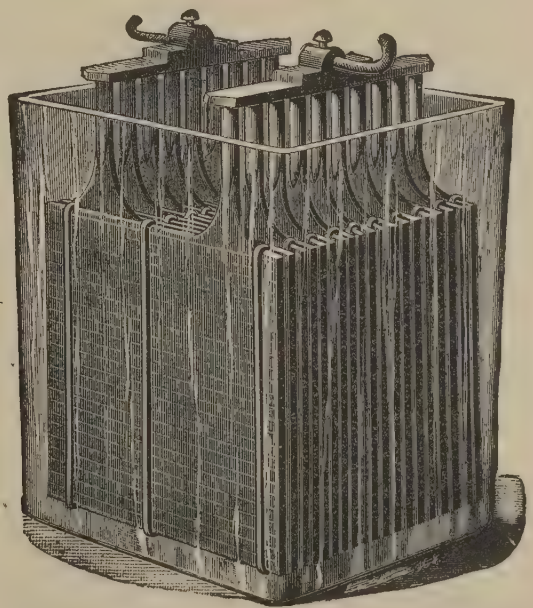


FIG. 108.—SINGLE ELEMENT STORAGE BATTERY.

When only one set of batteries is charged, the potential of the dynamo is itself suitably varied to give the proper charging current. When two or more sets are to be charged simultaneously the po-

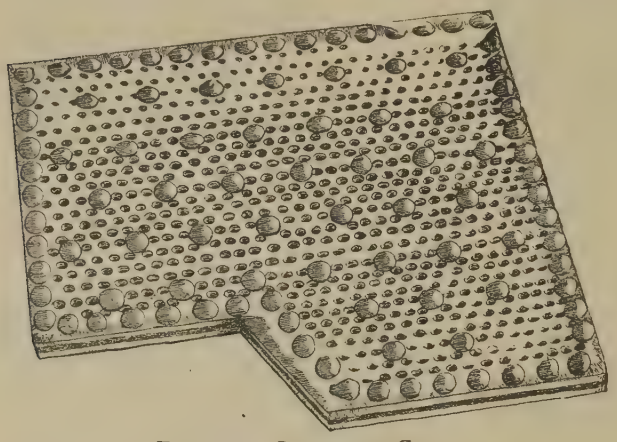


FIG. 109.—COMPOSITE GRID.

tential of the dynamo is raised to the highest point ever likely to be required, allowing sometimes as much as 2.4 volts per cell connected in series. A resistance coil is then put into circuit with each set of batteries. At the beginning of the charge the resistance is greater, so as to reduce the charging current to the proper value. As the "back pressure," or "potential," of the battery rises, in consequence of the charge, the current becomes reduced, and some resistance must be taken out of circuit to bring the charging current to the proper value again. It is found that batteries can stand a heavier charging rate at the beginning than toward the close of the operation. An excessive rate is always indicated by the "boiling" of the cells, in consequence of the rapid evolution of gas. When the charging has proceeded sufficiently long the "boiling" occurs even with a weak charging current. The cells are then said to be "full." The rise of counter electro-motive force is also used as an indication of the extent of charge, especially when the cells are sealed, and the evolution of gas cannot be so easily observed.

The electro-motive force of an ordinary lead cell is between two and two and a half volts, and the weight of the average lead accumulator is about 100 lbs. per H. P. hour stored. On account of their excessive weight other types of batteries have been devised, one of which, known as the alkaline accumulator, employs copper and zinc as the metallic elements, while the electrolyte is caustic potash. In a modified type of this battery the copper electrode is made with a dense copper coil surrounded by porous copper, and inclosed in a textile covering, while the other electrode is of iron which forms the walls of the cell itself, or retaining vessel, and becomes part of the negative pole. The electrolyte becomes potassium zincate. This battery weighs about fifty-five or sixty pounds per horse power hour stored, and is claimed to have an efficiency about equal to that of lead batteries. The former, however, are more generally employed.

The deterioration of lead storage batteries occurs from both chemical and mechanical action. The chemical reaction not being complete, the active material disintegrates, and the swelling of the plugs or plates of the active material causes the positive plates to buckle or warp, producing a short circuit; and this tendency is increased by any at-

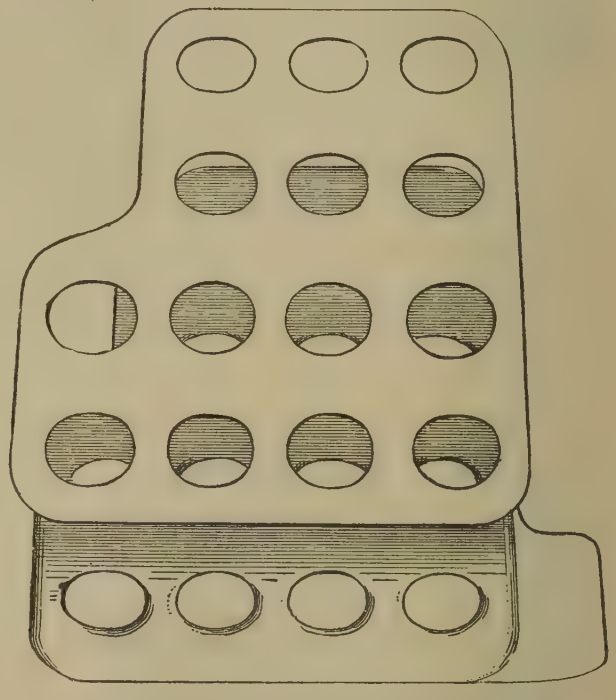


FIG. 110.—COPPER SHELF FOR SUPPORTING GRID.

tempt to force the output of the battery in order to meet the demands of grades or heavy loads. The life of the ordinary battery, if well made, is about six months, depending, of course, on the service required of it and the care it receives.

In the application of secondary batteries to the propulsion of street cars, the cells are usually arranged in trays, and these are placed upon the

FIG. 111.—STORAGE CAR, WITH BATTERIES IN PLACE.

car by pushing them from the outside through the open panels under the seats, as in Fig. 111, or these batteries may be introduced from the end of the car, an opening being provided in the end panel and also in the dash. Lead batteries for a sixteen-foot car to be operated on a road with no long grade exceeding five per cent., usually weigh, with the containing trays, 3,800 lbs. Very long grades or grades steeper than five feet in one hundred, will require the use of batteries having a larger capacity and, consequently, more weight.

The arrangement of the wires and connections in the car is such that, when the batteries are in place, automatic connections are made with the circuit leading to the regulating switch and motors. Any of the well known types of motors may be used with the secondary batteries, and the same methods of regulation may be employed as when using the direct current. It is customary, however, to regulate the flow of the current by changing the grouping of the batteries. In one system the 108 cells

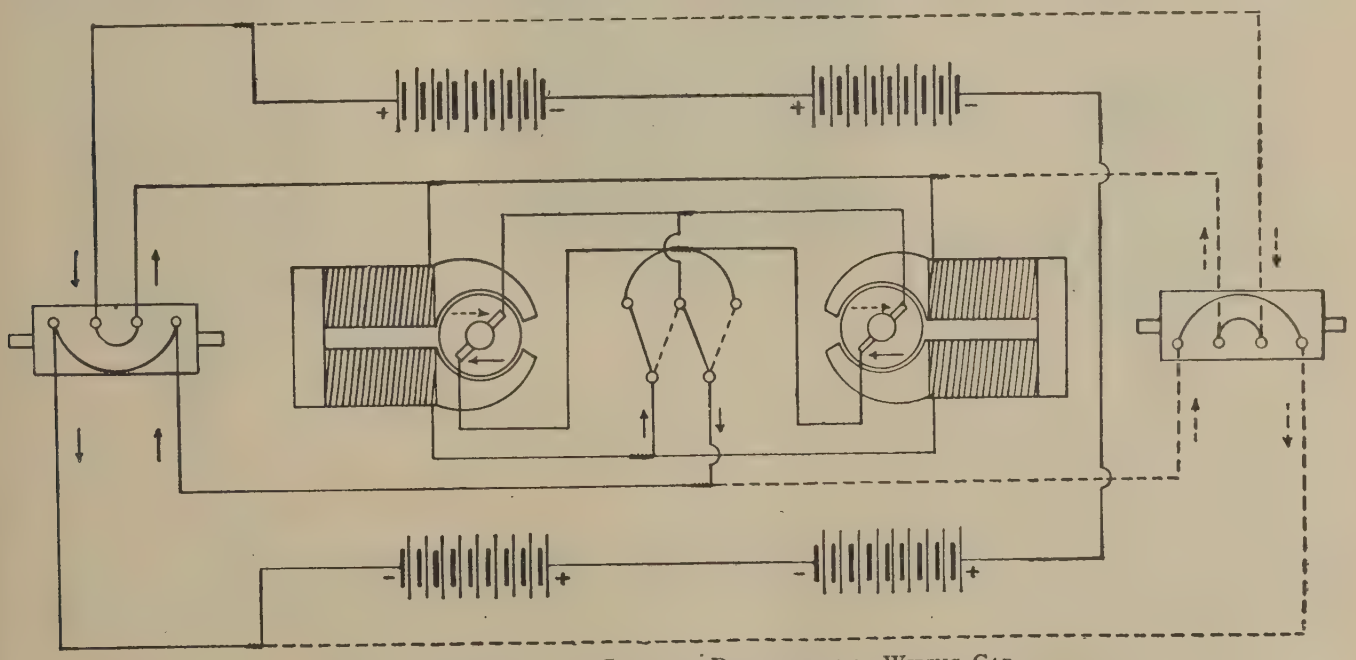


FIG. 112.—METHOD OF COUPLING BATTERIES AND WIRING CAR.

used are coupled in four groups, which allows for four different speeds. Fig. 112 shows the method of arranging the wires for a certain grouping of batteries. All the wires of the various groupings are connected to the switch stands, by means of which, from either end of the car, the various groupings are coupled in and the speed and direction of the car are regulated.

By tracing the path of the current over the full lines from the left hand regulator the revolutions of the armatures will propel the car to the left. From the right hand regulator trace or follow the dotted lines until they meet the full lines leading to either the batteries or motors, and the revolutions of the armatures will indicate the propulsion of the car toward the right, i. e., the car is propelled forward from either end.

Besides grouping the batteries as explained above, the motor may be regulated by utilizing the current of one group by itself for energizing the field magnets. In this case the motor may be employed as a brake for checking the speed of the car, and on down grades may be operated as a dynamo and made to restore energy to the batteries.

In the operation of street cars by storage batteries it is necessary to provide two sets of batteries, so that one set can be charged while the other is in service, and in addition to the usual equipment

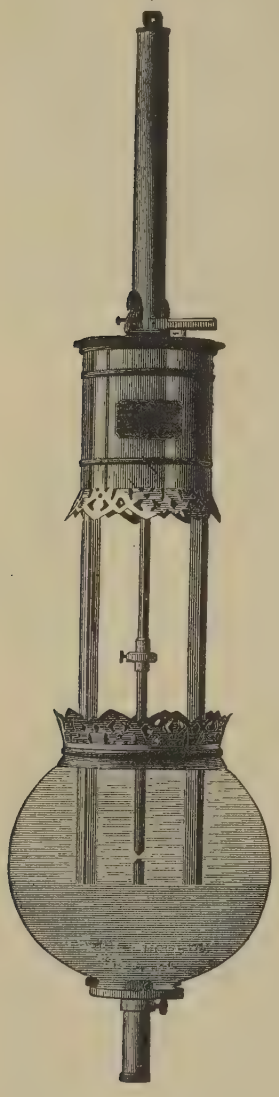


FIG. 113.—ELECTRIC ARC LIGHT.

FIG. 114.—CARBON POINTS—ARC LIGHT.

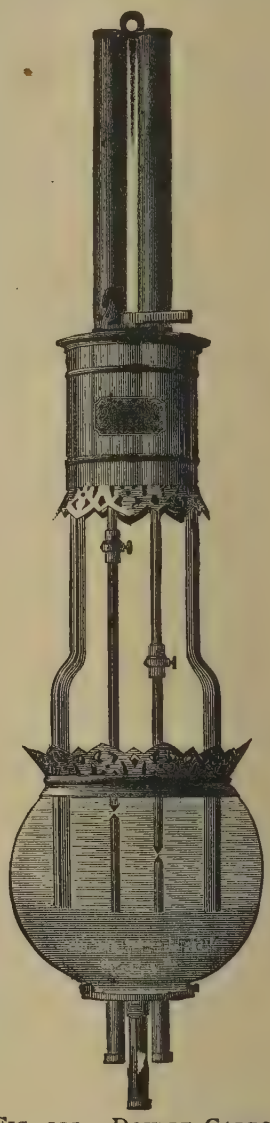


FIG. 115.—DOUBLE CARBON ARC LIGHT.

of generating machinery and batteries, a shifting device should be provided to facilitate the placing of the batteries upon the car and their removal therefrom.

ELECTRIC LIGHTING.

The practice of lighting electric power stations and cars by electricity having become general, it is highly necessary that employes should be familiar with the principles and mechanical details of this branch of the service.

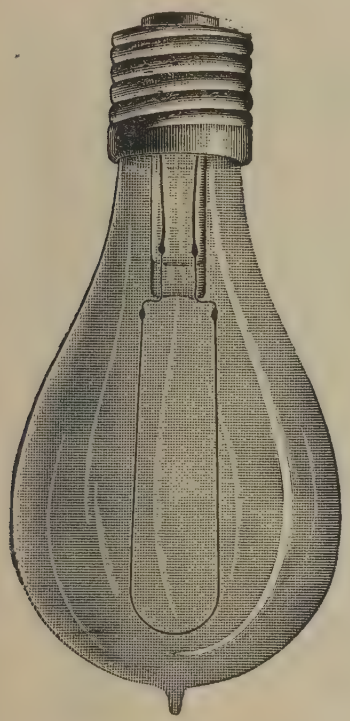


FIG. 116.—STANDARD INCANDESCENT LAMP.

FIG. 120.—VOLT METER.

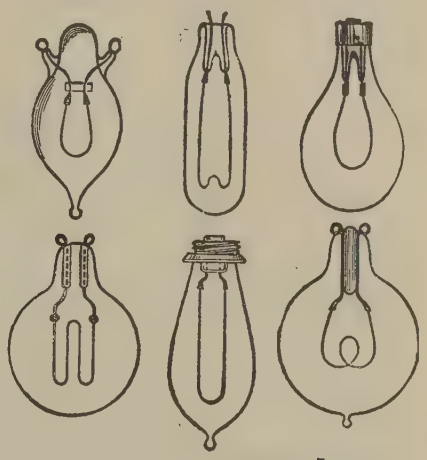


FIG. 117.—INCANDESCENT LAMPS.

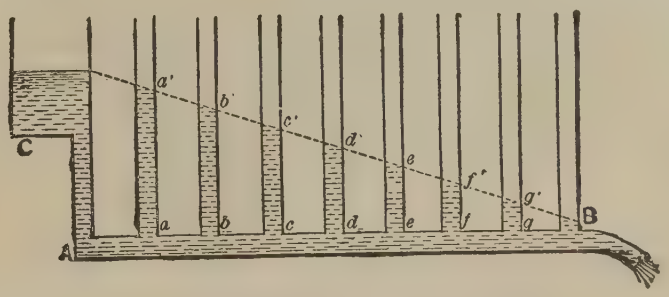


FIG. 118.—GRAPHIC ILLUSTRATION OF POTENTIAL.

To produce electric light, electric energy has to be converted into heat, and this is accomplished by introducing into a circuit, at suitable intervals, conductors offering a high resistance to the passage of the current. There are two methods of arranging the resisting medium, and the lights thus produced thereby have given their names to the two general classes of electric lamps, "arc" and "incandescent."

The arc lamp, Fig. 113, is formed by breaking the circuit and attaching to the terminal wires carbon rods or pencils of small cross section called electrodes. Now, if these electrodes be brought in contact for a moment and then drawn apart to a short distance, a kind of electric flame called the voltaic arc is produced between the carbon rods, and a brilliant light is emitted by their white hot points. The arc is called "voltaic" because it was first obtained by the use of a battery invented by Volta; and from the bow or curve shape of the flame between the carbons, when in a horizontal position, the term "arc," which is French for bow, has come.

As the electrodes are consumed carbon vapor is formed, which, being a partial conductor, allows the current to continue to flow across the gap, provided it be not too wide; but as this vapor has a very high resistance it, as well as the carbon points, becomes intensely heated by the passage of the current. It is noticeable in Fig. 114 that as a result of the heat and current a cavity or tiny crater is formed in the end of the positive carbon, and that the end of the negative carbon becomes pointed from a deposit of particles torn away from the other. The rounded masses or globules that

appear on the surface of the electrodes are due to deposits of molten foreign matters contained in the carbon.

To prevent the gap between the carbons from becoming too wide, arc lamps are constructed with a mechanism which automatically feeds one or both of the pencils into the arc as fast as they are consumed, and also serves to bring them together for an instant to start the arc again if by any chance it should go out. A great many devices have been invented to accomplish these results, but among them all one of the most simple is a lamp where the carbons are placed in a vertical position one above the other, the lower one remaining fixed, while the upper or positive carbon is placed in a holder which is held up by a clutch. The clutch is operated by means of an electro-magnet, through which all or a part of the current passes, so that in case the lamp goes out the clutch is released and the carbon falls by its own weight till it touches the lower one. Again the arc is formed and the clutch raises the carbon to the requisite distance. It also adjusts the carbons as the resistance increases by the burning away of the electrodes.

When the lamp is not in operation the carbons are usually in contact with one another. In addition to the regulating mechanism, arc lamps, which are usually placed in series in a circuit, are provided with a safety device operated in much the same manner by a magnet which automatically provides a path for the current around a lamp, in case it should get out of order, and thus prevents the failure of the other lamps.

Carbons for arc lamps are generally made of powdered coke mixed into a stiff dough and then moulded into rods by hydraulic pressure. After drying they are placed in crucibles and, being covered with powdered plumbago, are subjected to an intense heat for several hours, and then are copper coated. In order to prolong the life of arc lamps they are sometimes constructed with two or more carbon couples so arranged as to be brought alternately into the current. A lamp of this kind is shown in Fig. 115.

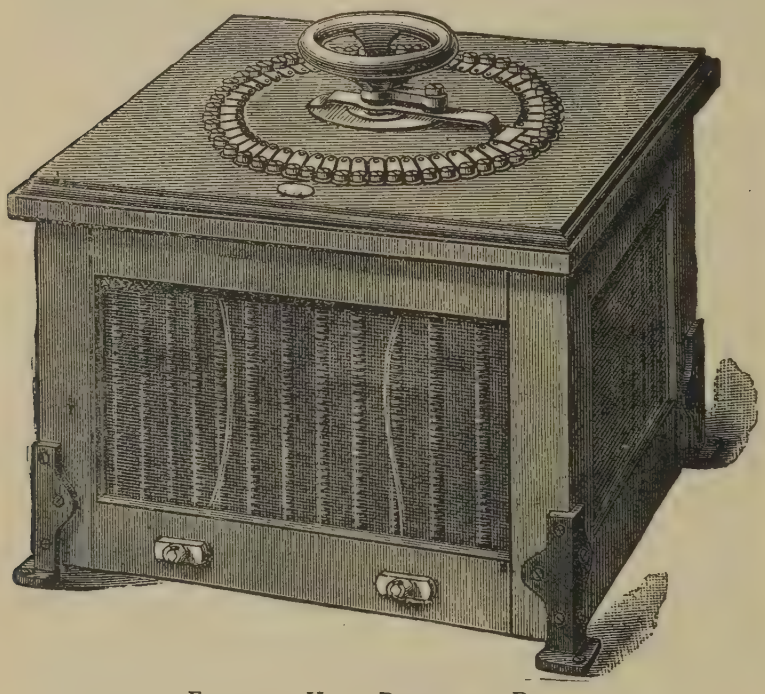


Fig. 119.—Hand Resistance Box.

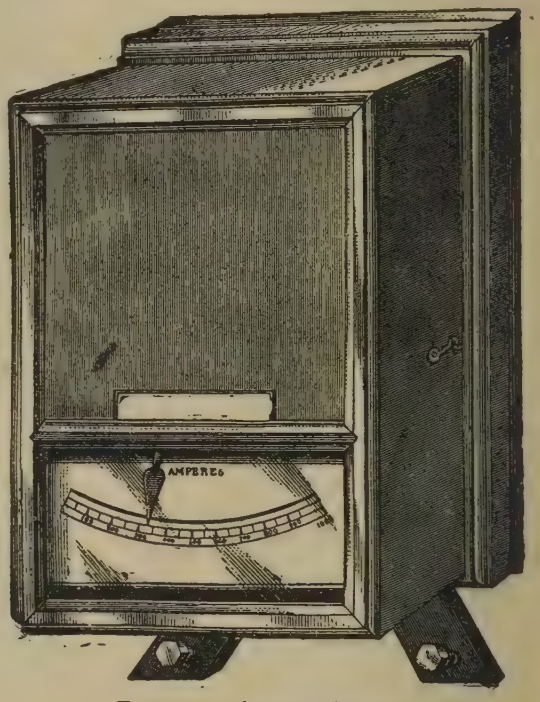


Fig. 121.—Ampere Meter.

The incandescent or glow lamp, Fig. 116, is made by introducing into the circuit a filament of carbonized fibrous material, which by the passage of the current becomes heated to luminosity, but is not consumed because of being placed inside a glass vessel from which the air has been exhausted.

The filaments are usually bent into the form of a

horseshoe but may be made in any form. The ends of the carbon strip are attached to platinum wires which pass through the glass walls of the chamber and are fused therein by melting the glass around them. To prevent the platinum wires from melting at high temperature the filaments are considerably thicker at the end connected with the wire, so as to offer less resistance to the current. The free ends of the platinum wires are connected with a double metal ring forming the base, and by screwing this into a socket connected with the circuit contact is made and the current passes through the lamp. A key is also provided for each lamp or for a number of lamps, by means of which the current may be turned on or off. Incandescent lamps for house and street lighting are generally connected to the circuit in parallel or multiple arc, by which arrangement, as explained for cars in parallel, only a portion of the main current passes through each lamp. But in street car lighting it is necessary to connect the lamps in series and to place a certain number on each car. The number depends upon the voltage of the current in the line and the candle power of each lamp. Ordinarily five lamps are used on each car, and the necessity of such an arrangement will be fully explained below as we study the value of electric terms.

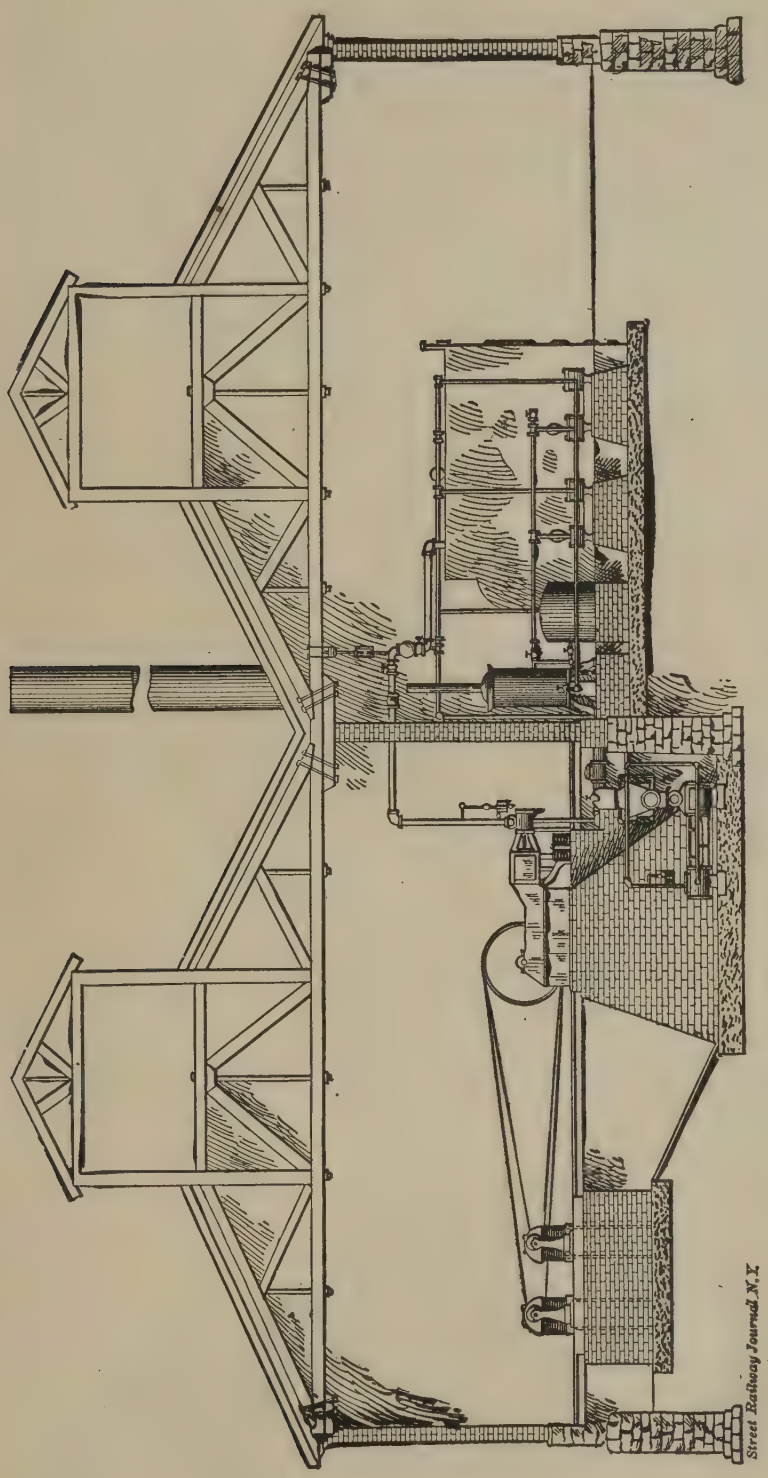


Fig. 123.—Typical Power Station—Direct Belting.

Incandescent lamps assume a variety of forms, as shown in Fig. 117. The position of lamps in the car, the switch and wire connections were shown in Fig. 81.

The light emitted by an incandescent lamp varies, according to the size, from two to fifty candles. The standard candle is one which burns two grains of spermaceti wax per minute. Well made lamps have a life of several thousand hours and the usual market price is from seventy-five cents to one dollar each.

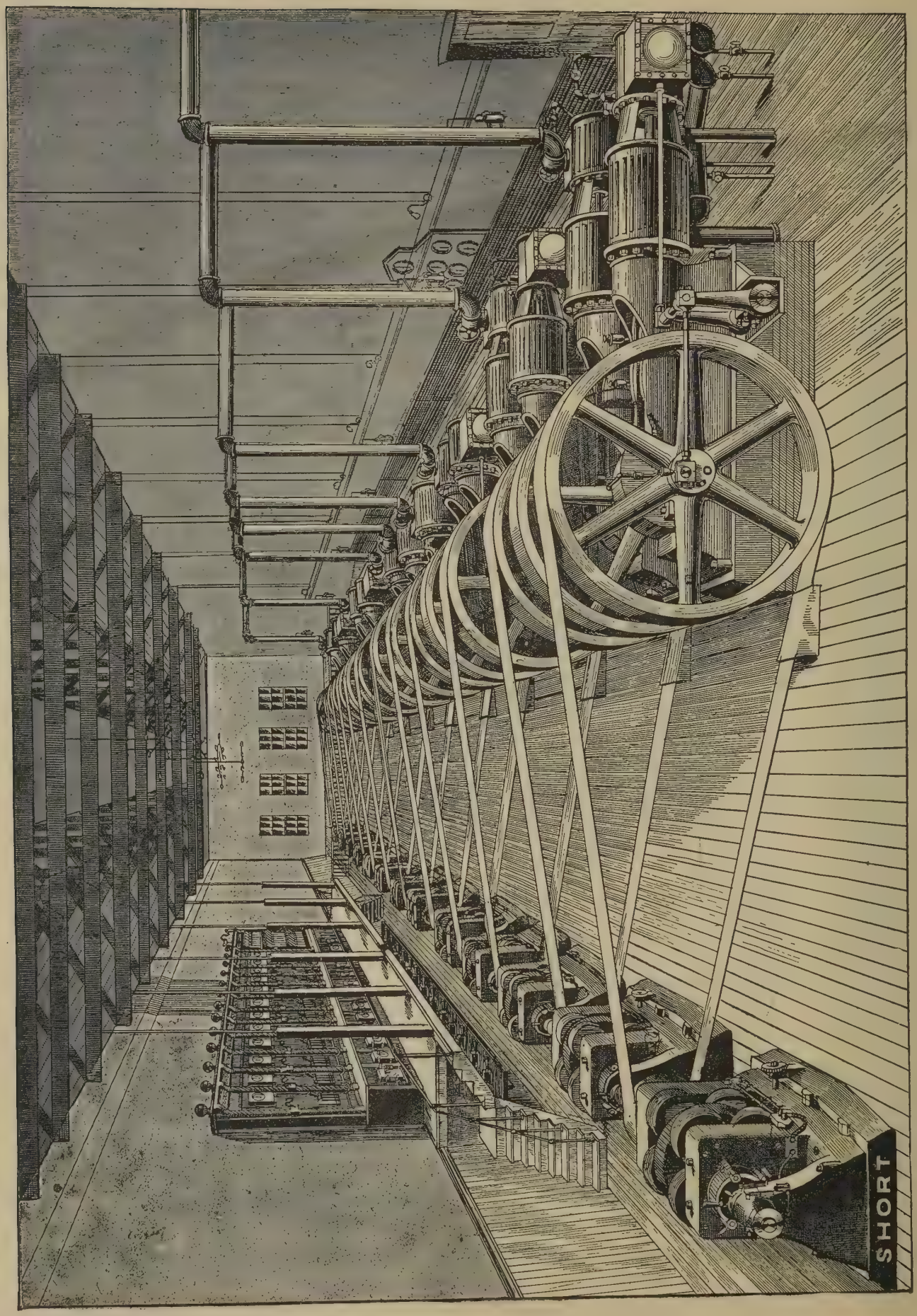


FIG. 122.—ELECTRIC POWER STATION—DIRECT BELTING—ROCHESTER, N. Y., RAILWAY.

Failure may result either from the disintegration or rupture of the carbon filament, or because the vacuum of the lamp chamber is not perfect.

ELECTRIC TERMS AND UNITS.

Every system of measurement is based upon some experimental fact or law. We can only measure an electric current by the effects it produces, and must use units adapted to its nature and properties in order to weigh, measure and estimate its kind, character and amount. Electricity being a comparatively new science, new units and new names have been given because none of the existing units, such as feet, pounds and gallons fitted the case. The following practical units *volt*, *ampere*, *ohm* and *watt* are, however, based on certain abstract units derived by mathematical reasoning from the fundamental units, length, mass and time. Unfortunately the words themselves have no meaning, for they are all proper names anglicized and given in honor of certain scientists who have distinguished themselves by their researches in the field of electricity or steam..

The *volt* is the unit of electro-motive force, written E. M. F. and this is only another name for the *force* which drives electricity through the circuit and is sometimes called the electric pressure.

The *ampere* is the unit of current and measures the *rate* at which electrical current is transmitted through the conductors forming the circuit.

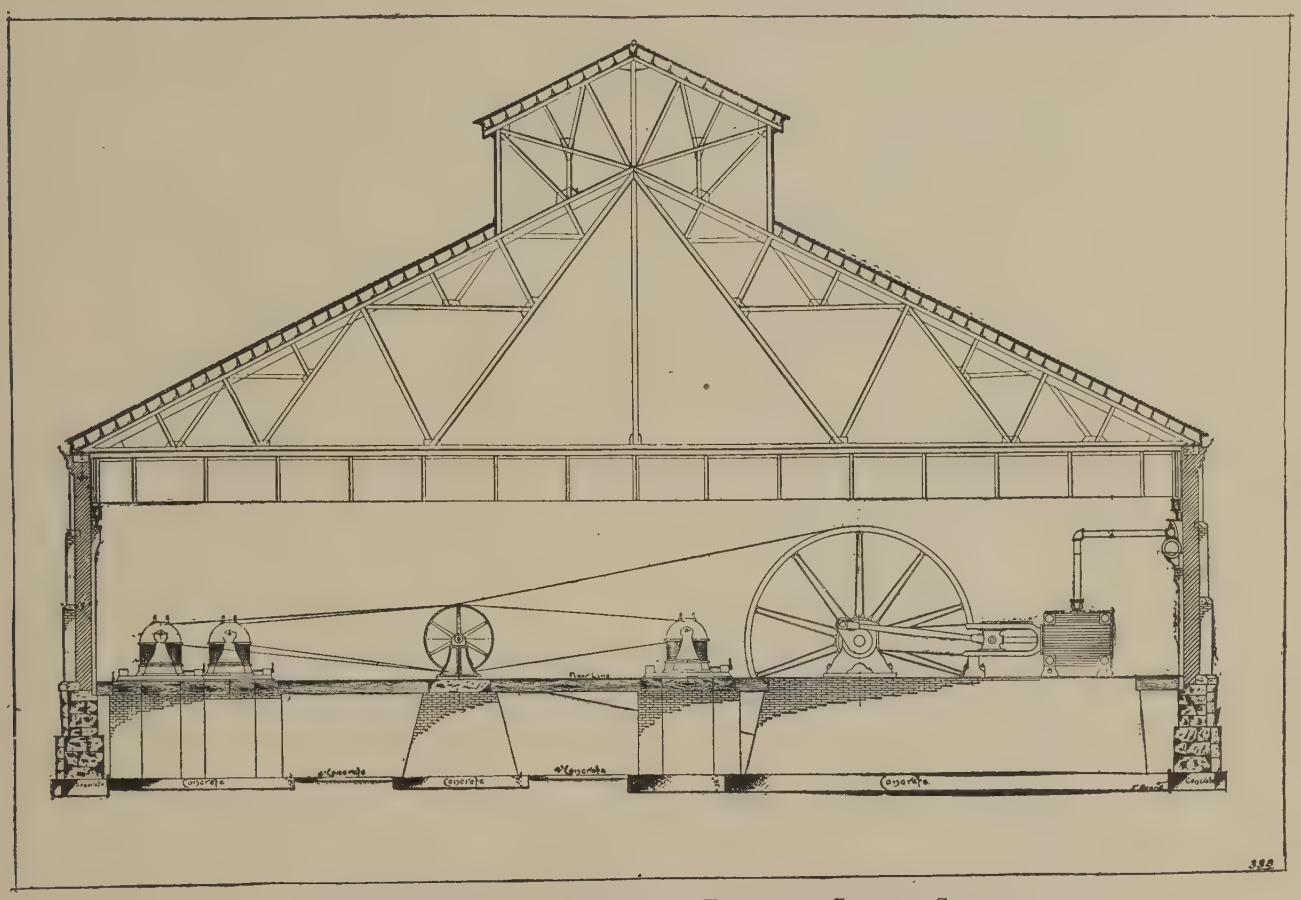


FIG. 124.—RAILWAY POWER STATION EMPLOYING COUNTER SHAFT.

The *ohm* is the unit of electric resistance in the conductor, and resistance is that which tends to stop the flow of electricity.

The *watt* is the unit by which to express the rate at which electric power is absorbed or developed in an electrical system, stated in terms of any two of the preceding units. It serves as a means of comparison between electrical and mechanical power.

Thus, to measure the power exerted by a cur-

rent in a wire, both the *volts* of electro-motive force and the *amperes* of current are measured and the two numbers are multiplied together, or the same result may be obtained by multiplying the square of the current in amperes by the resistance in ohms. The product is the same in either case, and gives the rate of doing work or the watts.

It has been found by calculation that a watt is equal to one 746th part of a horse power. Hence if the watts developed in any circuit be divided by 746 the quotient will be the number of horse powers to which it is equivalent. This does not include the losses which occur in conversion from electrical to mechanical energy or conversely. These must be determined separately, and this is usually done by the manufacturers of electric appliances who rate the efficiency of their goods accordingly.

In connection with the term "volts" the term *potential* or difference of potential is often used. This means that the voltage, or in other words, the number of volts at that particular place is, strictly speaking, the difference between the highest and lowest points of the circuit. The *potential*, the power of doing electric work, as well as the other terms used can be best understood by comparison with the case of a liquid. It is well known that the ability of a water supply to do work depends both on the quantity of water and also on the level or "head" of the source of supply as compared with some other level. Take the case of a water power and a turbine wheel, where there are a thousand gallons of water falling per given time from the height of one foot on the wheel; there is produced, it is assumed, one horse power; the rate of flow symbolizes *amperes*; it might be called a thousand amperes, and the height from which it falls might be called a volt, that is for pressure. If, now, the one gallon of water—or one ampere—be placed a thousand feet high, it will then have a thousand feet fall, or a thousand volts, and instead of a thousand amperes or a thousand gallons, there will be only one gallon or one ampere, and that small amount of water—a thousand times less—falling from a point a thousand times higher, will develop the same power on the turbine. The height from which it falls represents volts, and the amount of water is represented by amperes, and it is the combination of the two that produces useful work. In like manner the ability of electricity to do useful work depends upon the quantity and on the difference of potential between the place where the electricity is produced and some other place on the circuit.

The same and other analogies between liquids and electricity may be shown by the accompanying diagram. Fig. 118 shows a reservoir, or source of water, at C, communicating with the horizontal pipe, A B, furnished with open vertical tubes, *a* to *g*, and B. If the outlet at B were closed the water would stand at the same level as the source in all the tubes; but if it be allowed to escape freely from B, the level of the water in the branch pipes will be found on the inclined dotted line at *a'* to *g'*. It will be noted that the pressure per square inch becomes less or suffers a loss of head, or difference of potential, at any two points along the pipe, but at the same time the quantity which passes at any cross section of the pipe, in a given time, is the same. That is, it will be the same at B as at A. The same rule holds true in the case of electricity; the quantity—"amperes"—flowing through any conductor is the same at any cross section. If, however, the pipe conveying water should be opened at A the flow would be increased in proportion to the pressure at that point. It is very plain that the loss of pressure in the different sections of the pipe is due to the friction of the liquid against the internal walls of the pipe or resistance offered by the pipe, which in the case of electricity is measured by "ohms."

The quantity of water flowing through a pipe during a given time will be increased when the pressure is increased, or under the same pressure the quantity will be increased by substituting a larger pipe. Similarly, the strength of the electric current under a given pressure depends upon the size of the connecting wires, and it also depends upon the material of which the wire is made.

The resistance of conductors is governed by

three laws: First.—*The resistance of a conducting wire is proportional to its length.* If the resistance of a mile of wire be thirteen ohms, that of twenty miles will be twenty times thirteen ohms, or 260 ohms. Second.—*The resistance of a conducting wire is inversely* proportional to the area of its cross section,* and, therefore, in the usual round wires, *is inversely proportional to the square of its diameter.* A wire of twice the diameter and equal length would have only one-fourth the resistance, or would conduct four times as well. A wire three times the diameter would have only one-ninth the resistance and would conduct nine times as well. Third.—*The resistance of a conducting wire of given length and thickness depends upon the material of which it is made* —upon the specific resistance of the material.

The following table gives the relative resistance and conductivity of different metals in ohms, in a wire one foot long weighing one grain, silver being taken as 100.

SUBSTANCE	CONDUCTING POWER	RESISTANCE
Silver	100	0.2421
Copper	99.55	0.2106
Iron	16.81	1.2425
Lead	8.32	3.236
German silver		2.652

*Inverse means contrary or opposite. To *square* a number multiply it by itself.

The resistance of most metals is increased by raising the temperature; on the other hand, the resistance of carbon is diminished by heating.

The analogy of the flow of water in a pipe does not hold in all cases in explaining the laws of electricity. Take the case of a pipe of small area connecting two larger pipes; the quantity of water flowing through the pipes will be governed by the resistance or capacity of the smaller pipe. In the case of electricity, however, it will be governed by the total resistance of each section, or the resistance of the entire circuit.

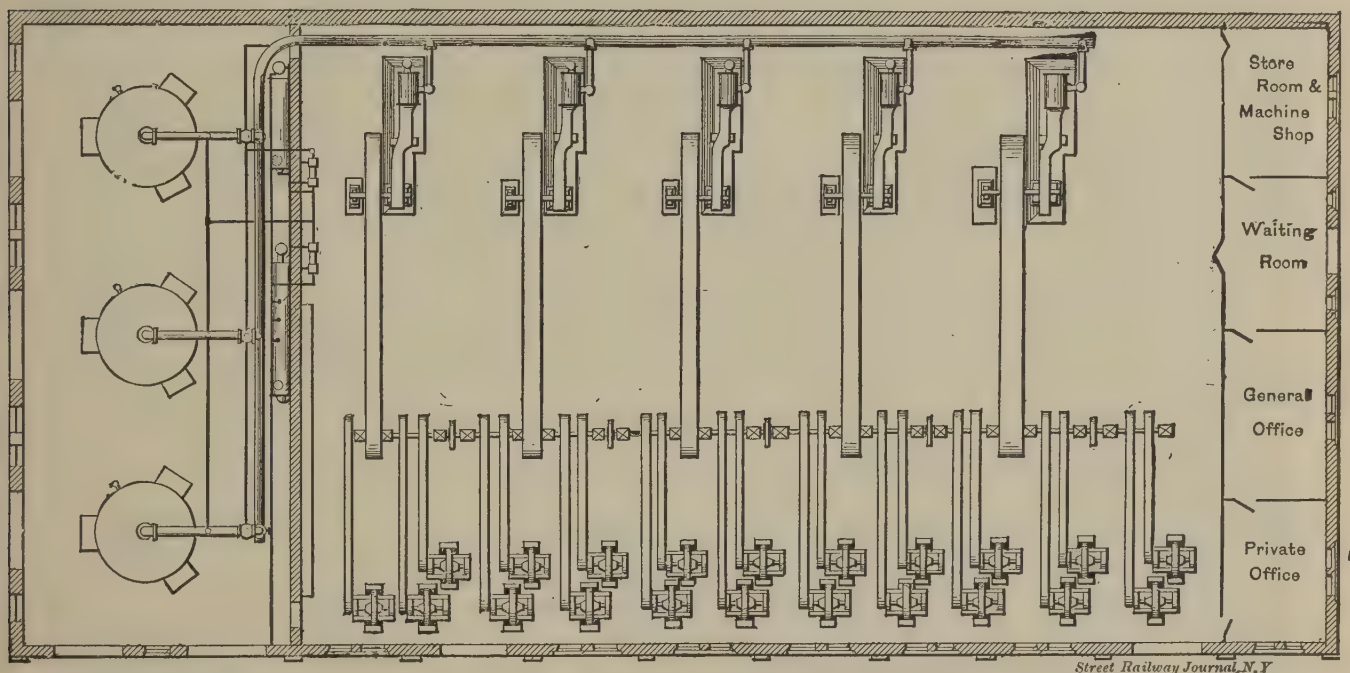


FIG. 125.—RAILWAY POWER STATION EMPLOYING COUNTER SHAFT.

The following law, which may be used as a rule in determining the number of amperes of current in a circuit, is true in a circuit where there is no counter electro-motive force:

The number of amperes of current flowing through a circuit is always equal to the number of volts of electro-motive force, divided by the number of ohms of resistance in the entire circuit, and the number of volts divided by the number of amperes gives the number of ohms.

The voltage or pressure in a circuit may be increased by driving the armature of the generator faster.

We are now able to understand why, in car

lighting, at least a certain number of lamps must be employed. The ordinary sixteen candle power lamp cannot be easily built to be operated on a potential of more than 100 volts, and as the voltage for operating electric roads is usually 500, it will require five 100-volt lamps to offer sufficient resistance for this voltage. A large number of smaller lamps could be substituted, provided that they be so grouped that the total amount of current flowing through each lamp is no more than that for which it was constructed.

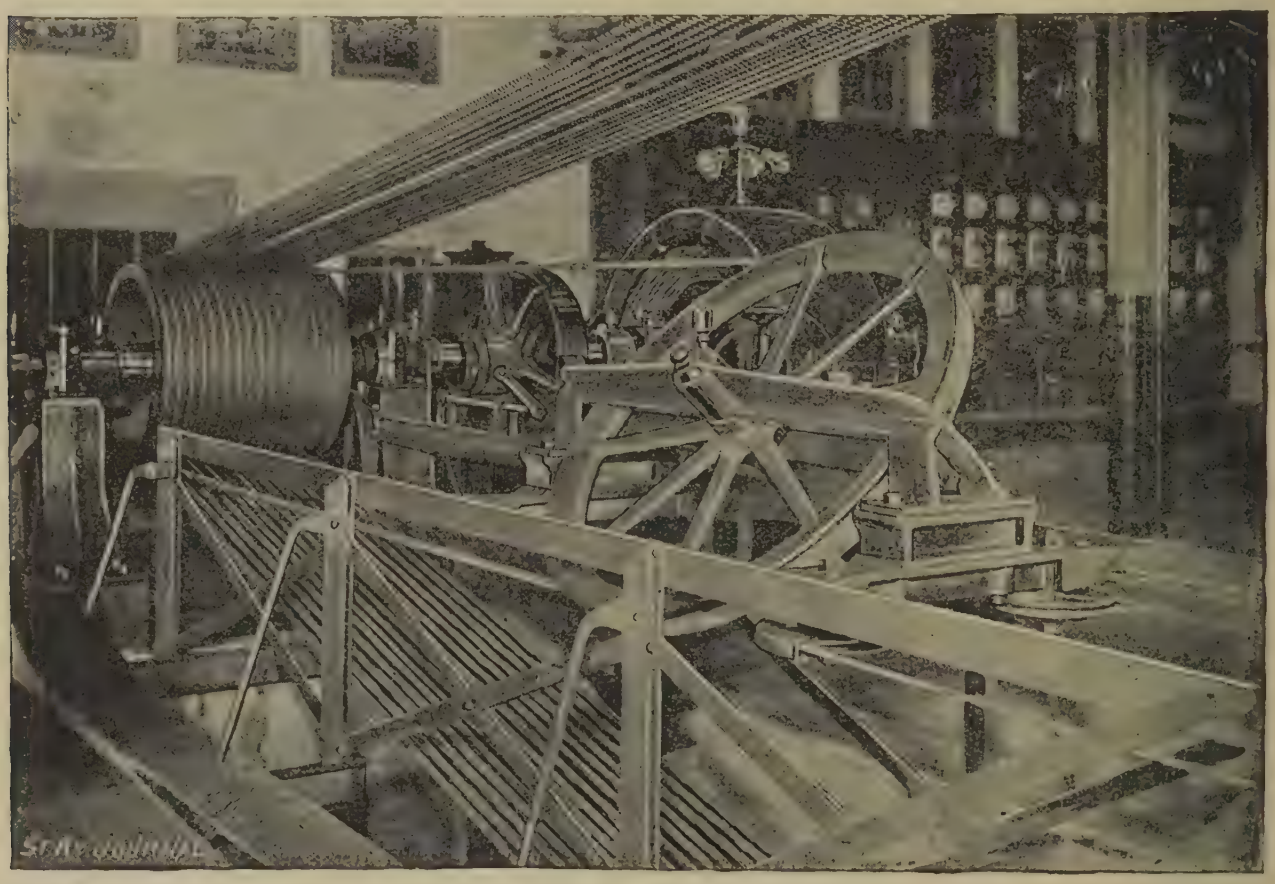


Fig. 126.—Power Station with Cotton Rope Drive.

We may consider briefly the danger element in connection with the operation of electric roads No matter what the quantity of electricity is, the resistance of the human body is so great that a person could not receive enough current to kill him unless there was a great amount of pressure. It requires a certain amount of amperes of current to pass through the human body to kill a person; but the resistance of the human body to the passage of the current is very considerable (from 800 to 1,800 ohms), and it may be compared to a pipe 100 ft. long, having a hole through it as small as a point of a needle. Very little water would pass through the hole without great pressure.

Like the water fall, a thousand gallons might fall from a height of one foot upon a person's head and not hurt him, but one gallon falling 1,000 ft. would have sufficient impact to kill.

The records show that a purely continuous current of less than 2,000 volts pressure has *never* killed a human being. An alternating current, however, is more dangerous, and people have been killed with alternating currents of lower voltage. But as the alternating current is not used for street railway purposes, it is not necessary to consider it in this connection, except in the possibility of a broken electric light wire, carrying an alternating current, falling across a trolley wire, in which case it would not be safe to receive the

current. About the only element of danger, besides that noted above, is the possibility of a person making contact with the current generated by a self-exciting continuous-current dynamo just at the instant that the field magnets were discharged. The extra current thus produced might be severe. This small possibility of danger can, however, be removed by the use of separately excited dynamos.

By reference to the above table, it will be seen that silver wire is the best conductor, but, it being too expensive, the next in the list, copper, is generally used for conductors. German silver wire, being a poor conductor and requiring a high temperature to melt it, is usually employed in making resistance coils, and these coils are an important factor in the operation of electric lines. Fig. 119 represents one form of resistance box.

The galvanometer is an instrument used for measuring the strength of an electric current, and depends for its operation on the fact that a conductor through which an electric current is flowing will deflect a magnetic needle placed near it. These instruments assume a variety of forms and names and are made by employing resistance coils or by other means. That for measuring amperes is called an *amperemeter* or *ammeter*, and is constructed with a very low resistance. In practice it is placed directly in the circuit. The *voltmeter* is made of high resistance, and is placed at the terminals or between the positive and negative wires. These instruments are so constructed as to read off the amperes and volts directly. See Figs. 120 and 121.

THE POWER STATION.

Here are located the boilers and engines or other source of power, the dynamos for generating the current, also the switch boards, including the instruments for measuring the current and the appliances for dividing the current and feeding the circuit.

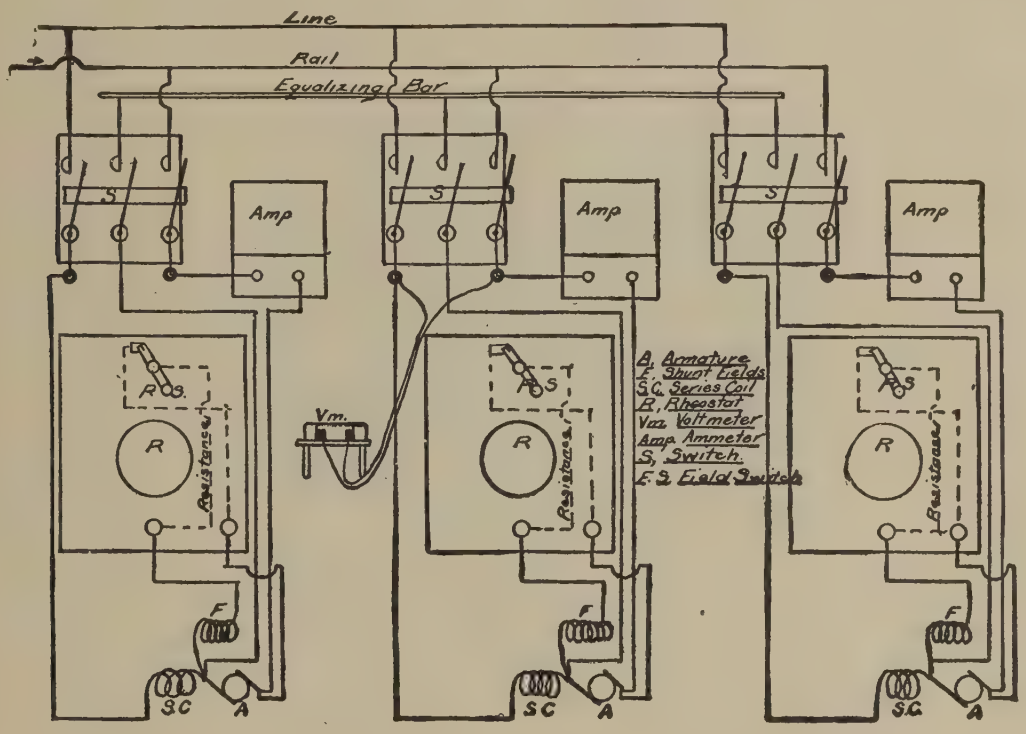


FIG. 127.—CONVENTIONAL DIAGRAM SHOWING POWER STATION WIRING.

The proper location for the power station is one of the most important questions to be decided in the installation of an electric plant, and in this matter the skill and good judgment of the engineer may save to a company several thousand dollars in first cost, a large amount in operating expenses and in cost of future developments. The main factors

of economy to be considered are the arrangement of feed wires, as before stated, a central location being desirable; ready access to fuel and water, the latter being very important in case condensing engines are employed. Of course, all these considerations may be ruled out by the high price of property or by local prohibitory legislation, in which case it will be necessary to locate in a less advantageous position. Where water power is to be employed, the natural location of the latter will preclude very much being gained by the skill of the engineer.

The location will also have much to do with the design of the building with reference to its architectural effect. If it is to be in the settled or growing portion of a city, the good taste and wishes of the community, by whose favor the line exists, should be regarded, and considerable attention should be given to external beauty. Fig. 122A is a fair specimen of pleasing architecture.

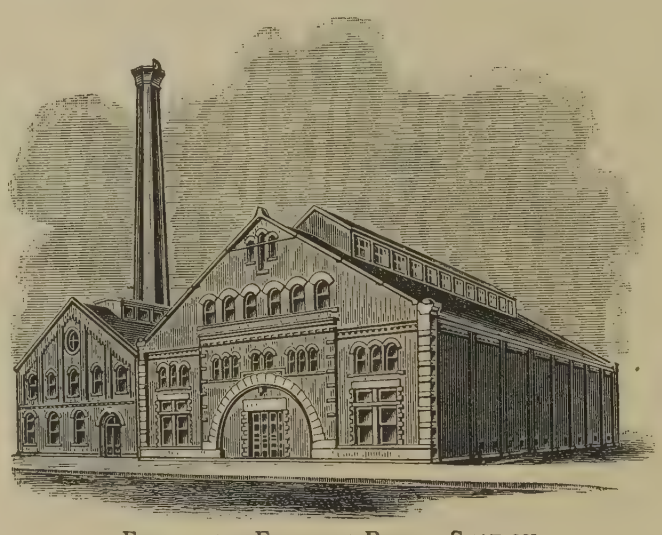


FIG. 122A.—ELECTRIC POWER STATION.

The boilers and engines play an important part in the production of the electric current, and the points of excellence in the various types of engines which engineers have devised for electric railway work will be treated in a separate chapter; in making a selection, however, care should be taken to secure economy, steady motion and high efficiency.

Not less than two units of steam power should be provided in electric railway power plants, and as few as is consistent with safety and economy. Engines for this class of work should be built very heavy and have ample fly-wheel capacity to provide for the excessive strains due to violent changes in load.

The amount of steam horse power to be provided per car will depend somewhat upon the grades in the line, the amount of traffic and amount of snow fall. It is safe to say that not less than twenty-five to thirty or even forty H. P. per car should be provided for roads operating a large number of cars. Small roads should have a larger average; not that this amount of power would be required for ordinary operations, but it should be in reserve.

A car uses, under ordinary conditions, one H. P. per car mile per hour. That is, a car running at a speed of five miles per hour requires five H. P., a seven miles seven H. P.

The relative position of the engines and generators in the power station is a matter to be regulated by the installing engineer. In some cases the engines are belted directly to one or more generators, as shown in Figs. 122 and 123. In other cases a counter shaft is employed and through this power is transmitted to a number of generators (Figs. 124 and 125) The counter shaft should be provided with suitable clutches so that any of the engines or generators may be cut out.

The selection and care of belts is an important factor in the economical operation of the power plant of an electric street railway. In the early history of the service it was difficult to get just what was required, but now there are various makes that fill, in all respects, the requirements of electric service.

It is not our province to discuss the merits of the different makes of belts that are in the market, nor to supply data and formulæ for ascertaining the width and strength of belts for a definite service. These matters are fully treated in works on belt transmission, and in the many admirable catalogues with which the trade supplies its customers. Suffice it to say that in order to secure a long life

ıd satisfactory service in any business, a belt ust be of ample width and substance to perform e work required of it, have proper care and be ounted with sufficient length to secure elasticity ıd adhesion. A record should also be kept of e performance of each belt to serve as a guide placing future orders. For driving street rail-ay generators, however, a belt having a capacity one and a half times at for ordinary work the same horse ower is recommended, r the reason that the ad varies suddenly ıd to great extremes ı account of grades ıd the cutting in or ıt of cars.

One school of prac-ce favors the direct oupling of engine and enerator, in which ase no belting is re-uired; this is usually ccomplished by ıounting the arma-ures directly upon the ngine shaft which ıay be extended in oth directions for the urpose. Friction oupling may also be mployed. Cotton ope belting is also em-loyed to a limited ex-ent (Fig. 126).

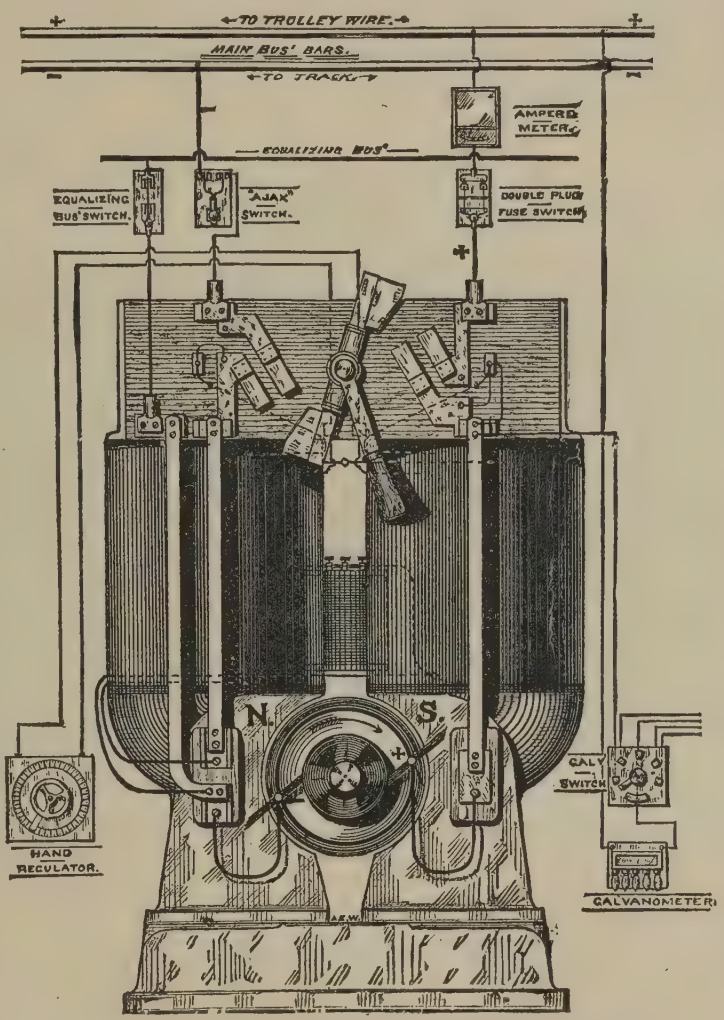


FIG. 128.—RELATIVE POSITION OF GENERATOR, METERS AND SWITCHES.

The cost of steam plant complete, including uilding and smoke stack, is, for high speed and ıon-condensing engines, from $45 to $60 per H. P.; or compound engines, $60 to $75 per H. P., and or electrical equipment, from $35 to $45 per H. P. Eight square feet of heating surface, evaporating hirty pounds of water per hour, is the usual unit f H. P. for sectional or water tube boilers, and fteen square feet the unit for tubular boilers.

Among the electrical devices which it is necessary to understand, one of the most important is the method of coupling two or more dynamos together, so that they may supply to a circuit a larger quantity of electric energy than either could do singly. This has to be done in a particular manner so that the machines will not interfere with each other; for, if not properly arranged one machine would absorb energy from the other and be driven as a motor instead of adding anything to the energy of the circuit.

The method of coupling depends upon the construction of the machine, and especially upon the way the field magnets are excited. Compound wound dynamos, in which the self regulating powers are perfect, may be coupled in parallel in a circuit without much difficulty, as shown in Fig. 127. A A A A represent the armatures of two or more dynamos, connected in short shunt.

By these means the two or more dynamos will exercise a continual mutual adjustment, resulting in an equal division of the work between them. Not only may similar compound dynamos be coupled, but, by additional precaution, those of different size, power and speed may be used together. In adding another machine, however, to those already in operation it is necessary to run it up to a proper speed and equal potential before attaching its terminals to the main conductor.

Fig. 128 further illustrates the relation of dynamos, switches and meters.

These diagrams are conventional; in practice however, a switch board is employed (Figs. 129 and 130) to which are attached the switches, meters, rheostats and safety devices in position to be readily inspected and adjusted. These switch boards are made more or less ornamental according to taste, the material being wood, marble or slate. In case a number of feed wires lead out from the same switch board, it is a good practice

Fig. 129.—Railway Switch Board Adapted to the Thomson-Houston Electric System.

to so connect them with a nest of push buttons located near the centre of the board, that by pressing any one of the buttons the meter will indicate the voltage of either line. A valuable type of individual switch is illustrated in Fig. 131. A drop switch or circuit breaker is also employed. This is constructed with an electro-magnet, and is designed to automatically break the circuit in case a dangerous current is generated. In place of the drop switch, or in connection with it, safety fuses are employed.

The use of fuses in electrical engineering is analogous to safety valves in steam engineering. They are intended to protect the devices to which they are applied, from excessive strain by an overplu of current. They depend for their action upon th fact that a current of electricity develops a certai amount of heat in its passage through a conducto the amount of heat depending directly upon th amount of resistance of the conductor and th square of the volume of current. If a metal, fus ble at a low temperature, is inserted in the circui and all the current allowed to pass through it, an its size is so proportioned that the amount heat generated by the passage of the norma amount of current will not melt it, such a devi constitutes a safety fuse, and any increase in th volume of current will develop an addition heating effect which will melt the fuse and brea the circuit at this point. In practice fuses are use on both bus bars of a switch board, on the car protect the motor and in the feed wires.

Solder is usually employed for fuses, althoug any metal easily fusible can be adopted. In a cases the fuse should be easily accessible, so th in case it melts from a temporary short circuit overload, it can be replaced by another fuse whe the danger has passed. For this reason, when use to connect two sections of a trolley wire, th

fuse, instead of being inserted directly in the overhead line is placed in the box, or one of the poles and wires are carried from each side of the fuse to each end of the trolley line section.

Care must be taken, in electric circuits in which high potentials are used, to have the fuse of such a length that when it melts the line terminals shall not be so near that the space can be bridged by a voltaic arc. To prevent the space from being bridged by the current the fuses may be bent over

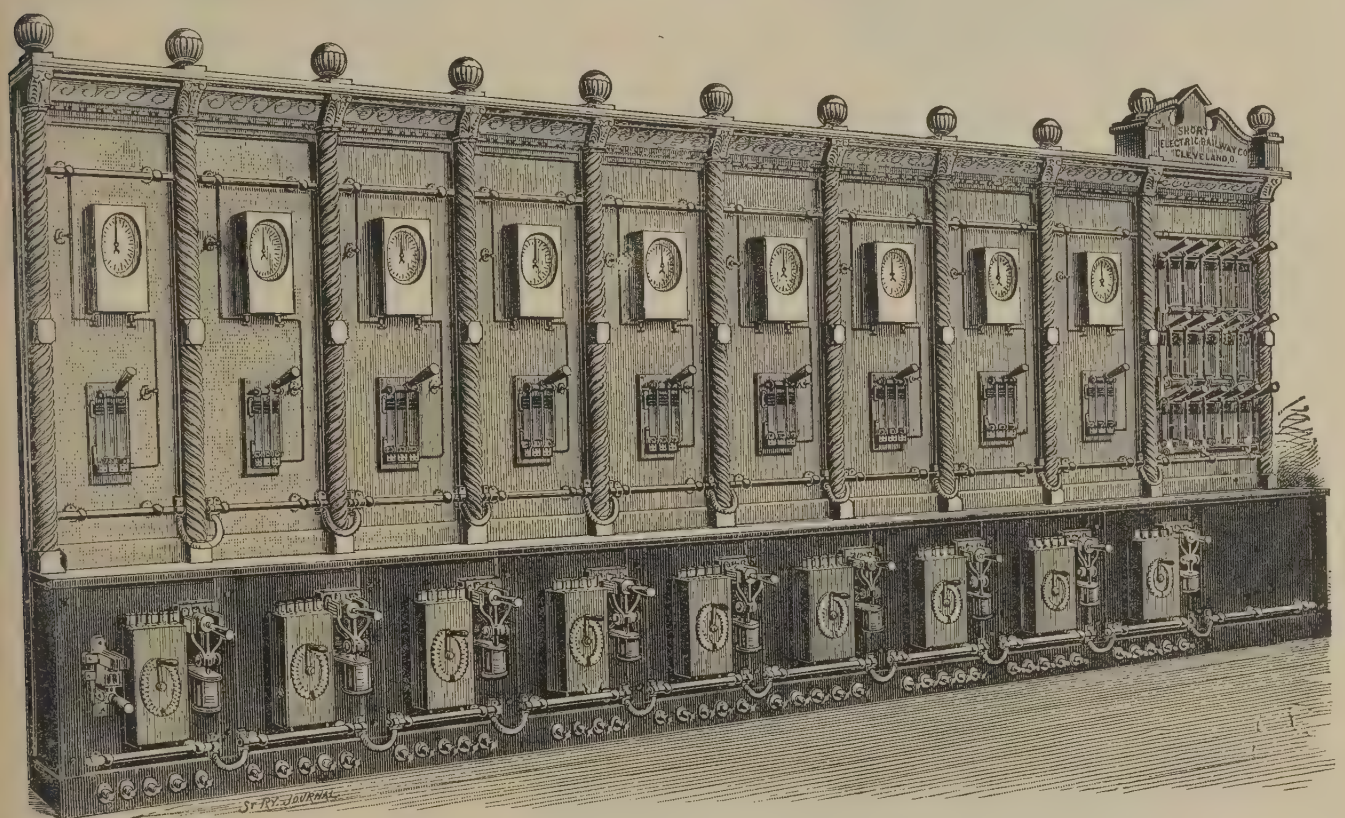


FIG. 130.—RAILWAY SWITCHBOARD ADAPTED TO THE SHORT ELECTRIC RAILWAY SYSTEM.

a board partition as shown in Fig. 132. The cross section of the fuse can easily be calculated according to the ampere carrying capacity desired. A margin of safety is generally allowed in figuring the size of fuses; that is, a fuse is made somewhat larger than would be sufficient to carry the normal maximum current in order to avoid frequent stoppages.

While fuses are an important and, perhaps, essential part of an electric transmission system, they are not infallible, since a fuse will sometimes hold its position and carry the current after it has been actually melted, being held in shape by an ozydized film on the outside.

LIGHTNING ARRESTER.

Another adjunct of the switch board is a "lightning arrester," one of which should also be placed on each car, and also at intervals in the trolley and feed wires. The object of the arrester is to protect the generators, motors, meters and other apparatus in the circuit from the destructive effects of a bolt of lightning or discharge of atmospheric current The term "lightning arrester" is a misnomer, however, for it does not arrest the current, but serves to change its direction and lead the surplus directly to the earth; it is, therefore, more in the nature of a safety valve.

Lightning arresters are dependent for operation on the tendency of a disruptive discharge to take a short cut across an intervening space rather than through a longer, though better, conductor. A simple form of arrester, and one which will help us to understand the more complicated devices in

practical use, is illustrated in Fig. 133. This device consists of two sets of serrated metallic plates placed near each other, one of which is connected

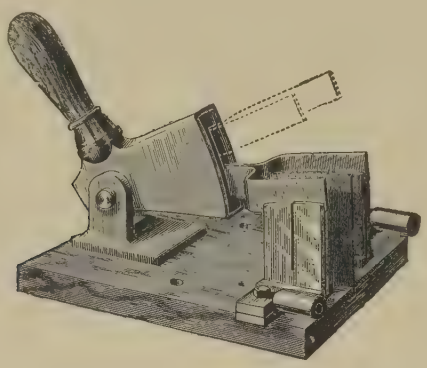


FIG. 131.—THE AJAX SWITCH.

with the line wire and the other by wire with the ground, so that, should a bolt strike the line, the current jumps the space and is discharged into the earth. This type of arrester is not suitable for use with heavy currents, owing to the fact that an arc once formed across the space, would be continued by the line current which would soon melt the serrated plates. This tendency is overcome by the use of carbon disks which are placed about one-sixteenth of an inch apart, one of which is connected to a ground wire, and the other, by a brass wire of small capacity, with the line. The lightning having bridged the space between the carbon disks, the line or quantity current follows the arc thus formed and instantly melts the small wire, and cuts off the ground. By an ingenious arrangement of disks, supernumary wires and levers the machine again sets itself, like a trap, and is ready for a second discharge.

Lightning arresters assume an almost endless variety of forms. In practice it is observed that

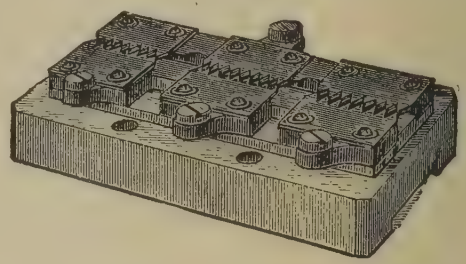


FIG. 133.—ORDINARY LIGHTNING ARRESTER.

the arresters on the cars or on the line operate before those at the power station, which indicates that the atmospheric current is not inclined to travel against the line current.

A second form of arrester is shown in Fig. 134 and is known as the swing ball arrester. This is placed upon the pole and is connected to the line wire by means of a tap shown at the base which is connected in the arrester to a discharge terminal. Above the terminal a metallic ball is suspended by a rod which is free to swing in any direction. The rod being connected to the ground, whenever the atmospheric discharge jumps from the terminal to the ball the arc causes the ball to swing out, and as soon as the arc ceases the ball returns to its original position and is then ready for a second discharge.

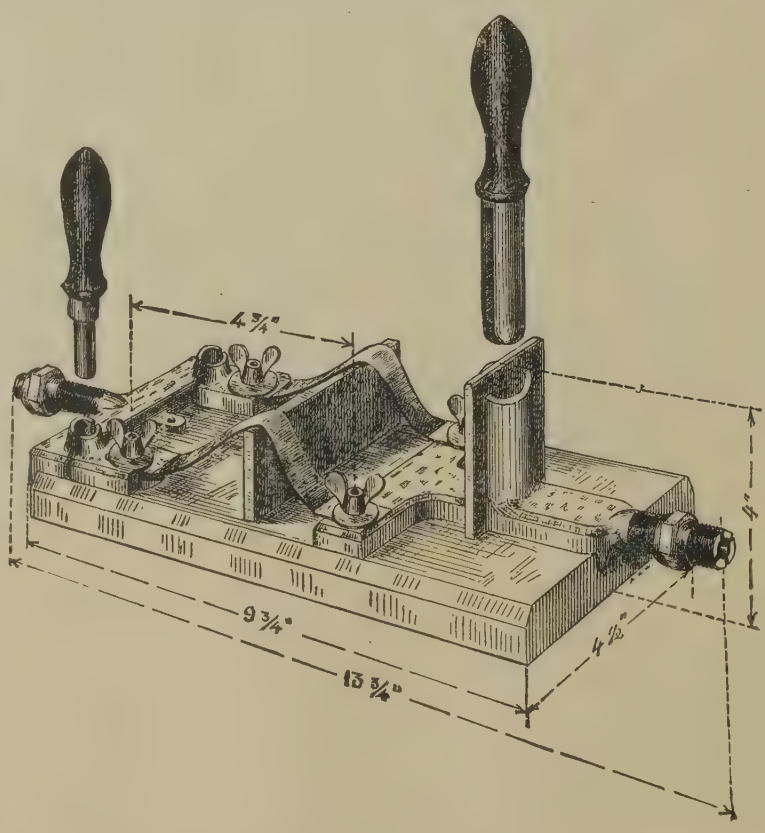


FIG. 132.—DOUBLE FUSE BLOCK.

THE CAR BARN.

This is an exceedingly important part of the equipment for electric lines, and its construction

and arrangement should have careful consideration. The building should be roomy and sufficiently high between joints to allow for wiring, so that cars can be shifted by means of the current.

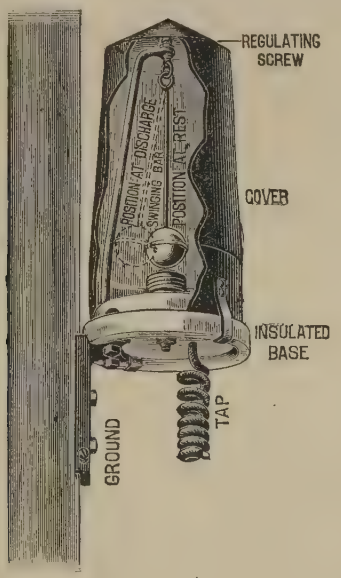


FIG. 134.—PENDULUM LIGHTNING ARRESTER.

In addition to the tracks, offices, wash room, elevators and transfer cars of ordinary barns, there should be provided a sufficient number of pits, over which the cars can run to facilitate repairs to the motors. These pits should be provided with steam pipes for warming, and with portable electric lights.

MACHINE SHOP.

The machine shop should be a part of the car barn or located near it, and should be equipped with a suitable number of iron-working tools. The power for these tools may be supplied by a small steam engine or by a stationary electric motor. Facilities should be provided for winding and making all necessary repairs to armatures.

The repair shop is the first and most important consideration in the building and operating of an electric line, and should be built and equipped before any part of the line has been put in operation; and, as stated above, the power to operate it may be derived from a stationary motor, deriving its current from the line, or by a steam engine. The tool equipment of the machine shop for the repairs on from twenty to sixty cars should consist of a lathe, a shaper, milling machine, drill press and emery wheel.

One or more wrecking wagons or patrol wagons are indispensable adjuncts to the repair equipment of an electric line. These should be provided with ladders, jacks and all necessary tools for making trolley repairs and for replacing or removing a derailed car. Powerful and well trained horses should always be at hand to haul such wagons at a moment's notice. A complete system of electric signals should be put in, with alarm boxes at suitable intervals along the line. Appliances of this kind are really economic factors in the operation of any line

A tower wagon should be provided as part of the equipment for line repairs and overhead work. This may be home made, with an adjustable ladder or one of the more pretentious wagons, such as are illustrated in Figs. 135 and 136, may be employed These wagons have an adjustable platform and are of a gauge of sufficient width to

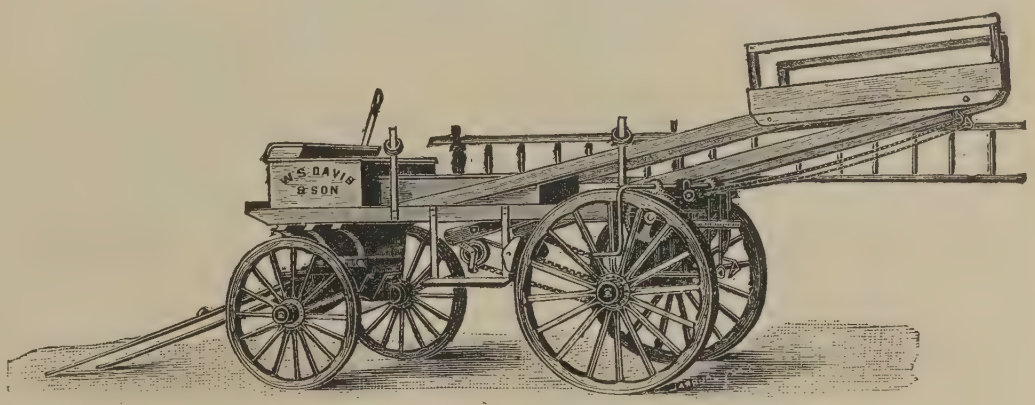


FIG. 135.—TOWER WAGON FOR OVERHEAD WORK.

stand astride the tracks, and when it is necessary to change position, the platform and ladder are readily dropped, when the vehicle assumes the appearance of an ordinary wagon. Beneath the seat is provided a box for the storing of the necessary tools.

A full complement of tools for a gang of five

men, including foreman, for overhead construction and repairs, would comprise the following; not that all would be absolutely required, but it will be found convenient to have them, and the list will form a basis for the organization of the different gangs. Besides the tower wagon there should be provided one light wagon and one reel wagon, two twenty-two foot ladders and one tool box, two sets each of large and small tackle, one dozen hauling clamps, two hauling clamp wrenches, four straps and vises, six pair six-inch gas pliers, six eight-inch side pliers, one bolt cutter, two twelve-inch monkey wrenches, six twelve-inch, flat, bastard files, two fourteen-inch, round files, two fire-pots, two railway soldering irons, two blacksmith hammers, one ratchet brace and three bits, two cold chisels, one hand saw, one twelve and one sixteen-inch screw driver, one wood mallet, one 100-foot tape line, one hack saw and blades, one acid jug with brushes, one fourteen-inch Stillson wrench, two 100-foot hand lines, one small soldering ladle, one hatchet, six lanterns, one bushel charcoal.

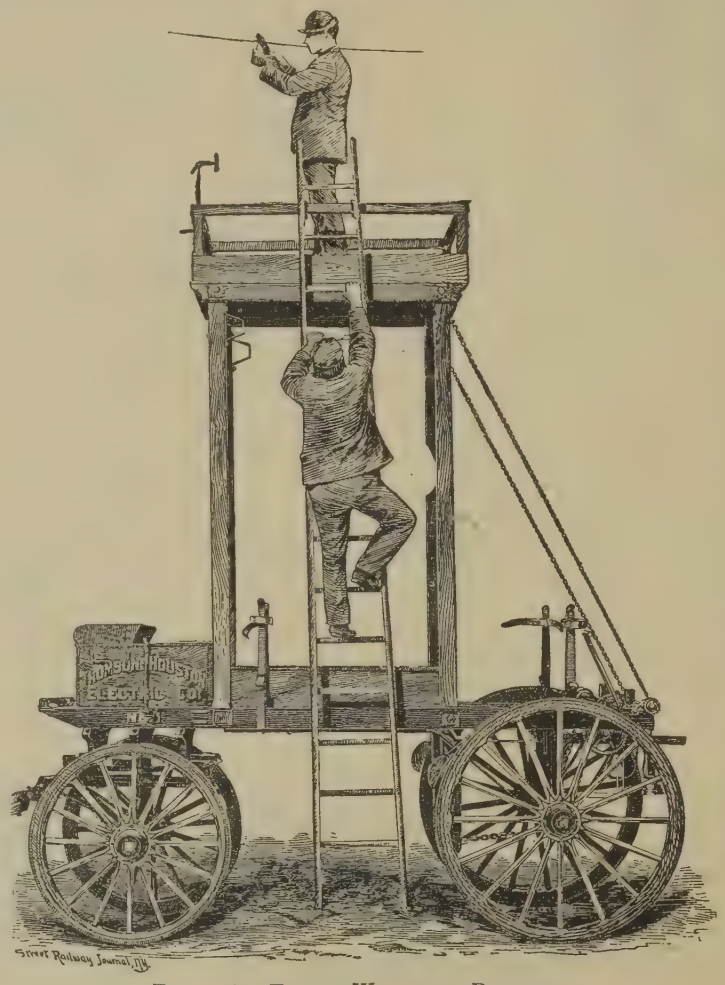


FIG. 136.—TOWER WAGON IN POSITION.

ROAD BED AND TRACK.

The greater weight and higher speed of electric cars as compared with horse cars, has given rise to new problems in track construction. No railway official, in the light of the experience already gained, would any more think of putting in the old time stringer and tram construction for an electric line than he would for a cable line. The requirements now are a rail of great vertical stiffness, a permanent track and durable material. The experience of the electric roads that have attempted to operate the cars over the old construction, has shown that there is more delay and a higher figure of operating expense arising from the faulty roadbed than from the electric appliances. (For detail of suitable track construction see a subsequent chapter.)

OPERATION AND MAINTENANCE.

A large per cent. of the operating expenses of an electric line is found in the repairs to trucks and motors, and in proportion as this expense is reduced, dividends increase; hence it is that this part of the work requires special attention from the management.

It is not the province of this chapter to treat of all the details regarding inspection and care of motors, for the reason that each particular type of motor requires some special instruction as to repairs and means of detecting faults. These will be found in books of instruction usually furnished by the promoters of each particular system, while a code of special rules for the guidance of conductors and motor drivers will be found in a separate chapter, all of which should be carefully studied both by the management and by the employes whose duty it is to handle the machines. There are some general instructions, however, which will

apply to every class of motors, which we compile from the knowledge that has been gained by the experience of practical engineers connected with the work. These are given as suggestive, and any manager can determine for himself how far they are applicable to his particular equipment and how far he can neglect, adopt or improve upon them with a view of reducing the repair account. It is safe to say that in no line of business and with no other machine is the old adage, "A stitch in time saves nine," more applicable than in the operation of an electric railway motor. It is never economy to run a car until something gives out, but there should be constant, intelligent and rigid inspection which will usually remedy the trouble before a breakdown occurs. Any defect, no matter how slight, whether it be a loose bolt or a worn bearing, will quickly generate other defects which will multiply in an alarming degree, but which, if promptly remedied, will avoid the necessity of taking the car to the repair shop.

A proper system of inspection requires that cars be run over a pit each trip and examined as to brushes, commutator, brush and field terminals, pinions, gear wheels, etc. In addition to trip inspection the motor should be run over the pit and inspected and cleaned every night, and all bolts, nuts and gears should be tightened up, special attention being given to wipe clean the gears, rocker arms, commutator and oil cups, also the switch stand and all switch connections. The fact should never be lost sight of that dust, dirt and water are the great enemies of an electrical machine for they aid in starting short circuits which result in serious burn-outs. For night inspection one man will be required for every ten or fifteen cars, depending somewhat upon the type of motor used. Of course with the use of gearless motors the inspectors' work will be very much reduced, and a larger number of cars can be inspected. The light tools with which an inspector should be provided comprise three monkey wrenches (from six to fourteen inches in size), one pair of six-inch pliers, a hammer, cold chisel, soldering furnace and iron and one ten-pound sledge hammer.

In addition to the night inspection, as often as once a week, the car should be run over a pit, and all pans, casings and screens removed and cleaned and the car thoroughly examined from below.

Particular attention should be given to see that the connecting cables are in good condition and that the insulation is not chafed or broken. Enough extra cars should be provided to allow of such weekly inspection without reducing the number of cars in service. As faults can usually be more readily located when the car is in motion the inspector should occasionally run the car and should also watch the motor while it is being run.

Repairs to motors also depend largely upon the care exercised by the motor driver; and to secure good men requires an equal degree of care on the part of the management. As a general rule, it will be found that old horse car drivers make the best motor drivers. They should be men who are always clear headed and cool in emergencies. Before being assigned to the new duty, however, they should be required to gain some slight knowledge of mechanics, and it is a good plan to give them three or four weeks' training in the repair shop, and such shop experience will be found to be worth to the management all it costs.

Drivers and conductors should not be allowed to take charge of an electric car until they have been carefully instructed and are able to pass an examination on their instructions. They should be assigned to duty with an experienced crew during a number of days of regular work, and then should be allowed to handle the car for three or four days under the immediate direction of an experienced instructor.

In addition to the training given on the cars, a set of motors should be mounted in some convenient place about the repair shop or barn where both drivers and conductors can have access to them and be taught how to operate and inspect them, how to adjust brush holders and brushes, and to properly handle the cut-out and controlling switches, and also how to disconnect the motors. They should learn how, by sound, to detect loose bolts, and also how to detect and locate electrical troubles. It is

not enough to tell men that a switch moved in a certain direction produces certain results; they must be required to move the lever and practice all the details over and over again until they are familiar with the mechanism, and, after receiving their instruction, should be frequently examined as to their knowledge of the matter contained in their book of instruction. The matter of inspecting employes can no more be neglected with safety than can that of the motor.

The life of gears and pinions on double reduction motors varies, with many different conditions, from one to four months for pinions and from three to nine months for gear wheels. Where dust boxes are used the life of gears and pinions is materially lengthened. A great deal of experimenting has been made with the material for both gears and pinions, and after a great deal of money spent in this direction, the following two combinations are recommended: Cast iron for the split axle gear, wood-filled gear for the intermediate, cut steel for the intermediate pinion and cast iron for the armature pinion. By the use of this combination, with the axle and intermediate pinion running in an oil-tight casing a very long life is obtained. Where the factor of noise is considered, a combination of rawhide pinions with metal gear is found to give the best results. Raw hide pinions, however, must be of thoroughly seasoned material and carefully put on to produce the best results. The use of an inferior article is an expensive luxury. The elimination of all gears, however, is a result confidently looked for in the near future of electric traction.

The brake equipment of electric cars varies largely with the grades in the line and the weight of the car operated. From the experience of roads that have been the longest in operation and have tried various means of brakes, it is found that automatic air brakes of some of the well known types give by far the best satisfaction, provided the expense of first equipment is not prohibitory.

It is not only recommended that motors, cars and overhead work receive frequent, regular and careful inspection in order to secure economy in operation, but the power station should also be included. The engines, boilers, generators, belts, switch board, shafting, pulleys, pipes, heating apparatus and all the light machinery, need the inspector's attention. The very fact that an inspection is regularly made and expected will compel employes to greater effort in their several duties.

The care of track and appliances for the removal of snow and sleet both from the roadway and overhead wire will be treated in a separate chapter.

CHAPTER II.

CABLE TRACTION.

Having studied the essential points relating to electric traction for street cars, we have next to learn the mechanical details of some of the leading cable systems. By "cable haulage" we mean the working of street or other railways by the employment of a continuously moving, endless, wire rope carried on pulleys within a slotted tube placed below the surface of the street, or between the rails of a surface or elevated road; this rope to be driven by means of a stationary engine, or other power, situated at a suitable point near the line, and the motion of the cable to be intermittently communicated to the cars by means of a suitable gripping device attached to the car.

Let it be understood that we are not to attempt an exhaustive treatise on cable traction, one that will embrace all the various systems so far proposed, for such a work would exceed the limits of this volume, as will be readily understood when we state that we have in our office a list of 1,000 patents, issued in the United States alone, relating to this subject. Nor are we to give all the technical details relating to the cable road construction, for we do not propose to invade the province of the constructing engineer, but we shall try to present some of the plans employed in the construction of the more prominent lines that have been long in operation, with enough of data to enable engineers to compare notes, and from which street railway managers, stockholders, and local authorities can learn the essential points when they wish to investigate the system with a view to its adoption. We shall also have in mind the ordinary street railway employe who must know enough of the relation of the various parts to be able to operate a line successfully and safely, and lastly, the unprofessional reader who simply wants to inform himself regarding the different methods of mechanical traction, that he may be abreast of the times.

It is eminently proper, whenever treating of cable railways, that the early workers in this field should receive due credit for the ingenuity manifest in adapting the principles of cable traction to street railways, and the courage displayed in making a practical trial in the face of the many obstacles which beset their first project. While the mere idea of cable traction was not new at the time these men began their work, the principle, as is well known, having been successfully employed upon certain railways and in mines for many years, and the essentials of the present system having been suggested some years before by E. S. Gardiner, of Philadelphia, and others, there is no evidence that the men who made the first practical test in San Francisco, Cal., in 1873, had any previous knowledge of such suggestion or description; hence we are bound to recognize Andrew S. Hallidie, of San Francisco, and his associates, Asa E. Hovey, William Eppelsheimer and Henry Root as pioneers in the business of operating street cars by means of a cable, slotted tube and grip. Although the plan itself has involved much ingenuity, still the grip in its relation to the cable is a most unmechanical device. It has served its purpose well, however, and still holds the field against all competitors. The idea itself, as well as the fact, has served a purpose, for it became a seed thought which has found lodgment in the brain of many an inventor, and in this line during the last few years human genius has won most signal victories (on paper).

THE STREET CONSTRUCTION.

This is the most important factor in a cable system, since it is the chief item of expense in building. It embraces the slotted tube, with carrying pulleys, vaults for same and drain pipes, also the pavement, track rail, etc. The required dimensions and strength of this tube depend upon many con-

ditions. It will be observed by reference to the accompanying figures that it is virtually an arch with the keystone left out, hence it must be constructed with sufficient strength to resist the side pressure due to the packing of the soil by heavy wagon traffic, and, in cold climates, the enormous pressure due to the expansion of the soil by freezing.

In the construction of almost any grip system it is first necessary to excavate a trench along the line of the road bed, about four feet deep and three feet wide, with side chambers every four or five feet, of sufficient width to receive the iron yokes which form the frame work of the tube or conduit; or the excavation may be made the full width of the track or of both tracks. If the formation is of rock the trench must be formed by blasting. In case the line is to be built upon made ground, or where the soil is light and porous, it is necessary to provide, as a support for the conduit, concrete foundation piers placed at suitable intervals and of sufficient depth to insure a firm foundation. In extreme cases it may be necessary to drive piles as an auxiliary support to the piers.

The yokes may be made of cast iron rolled or steel, the choice of which depends largely upon the cost of the material at any particular locality and also upon climatic conditions. It has been found that yokes made of cast iron generally resist frost pressure better than those made of wrought iron, doubtless because they are made heavier, and have therefore greater compression strength. In case wrought iron yokes are employed they should be entirely embedded in concrete, to prevent their too rapid disintegration in the soil, a tendency to which wrought metal is more subject than cast. In the early construction of cable roads both cast and wrought iron yokes were employed, and, also, the sides of the conduit were formed of plank; in fact, wood entered largely into the construction, as will be seen by reference to the accompanying figures.

As shown in Fig. 137, the tube was placed centrally between the rails, and was formed by the cast iron yokes H, placed about five feet apart; these carried the parallel slot rails J J, leaving a slot about seven-eighths of an inch wide, through which the shank of the grip could pass into the tube. C is a grooved pulley supporting the cable B, these pulleys being placed along the line at intervals of about forty feet.

The internal dimensions of these first conduits were, below the slot rails, about twelve by fifteen inches, or twenty-two inches in depth from the surface of the street. It will be observed that the slot was placed to one side of the conduit, while the cable and supporting pulleys were mounted in the centre; this was done to accommodate the peculiar form of the grip then employed, and also to prevent dirt and water from falling upon the cable and the pulleys. This method of mounting the cable and pulleys to one side of the slot is generally followed in cable road building, except on lines where a bottom grip is used, in which case it is customary to mount the cable directly under the slot.

Following the development of cable road construction we find, for a time, that wrought iron or steel yokes were substituted for those of cast iron, and in the earliest types these were made of old railroad rails bent in the form as shown in Fig. 138, with horizontal T iron braces to support the slot rail. Fig. 139 shows a form of construction in which inverted T rails were also used for forming the slot rails.

Fig. 140 represents a form of wrought iron yoke having members specially rolled for the purpose, and which has been extensively employed. This construction gives a conduit of sufficient depth to provide for quite an accumulation of dirt and snow without interfering with the operation of the carrying pulleys, and in which the carrying pulleys may be mounted without a specially prepared pulley vault. There is one serious objection to this construction, however, and that is, the braces interfere with the work of cleaning the conduit, which is usually done with shovels having long, thin handles, which are thrust into the conduit through the slot, and the workman by bracing the handle against his foot, placed over the slot, scrapes the accumulation from one section to the other till a

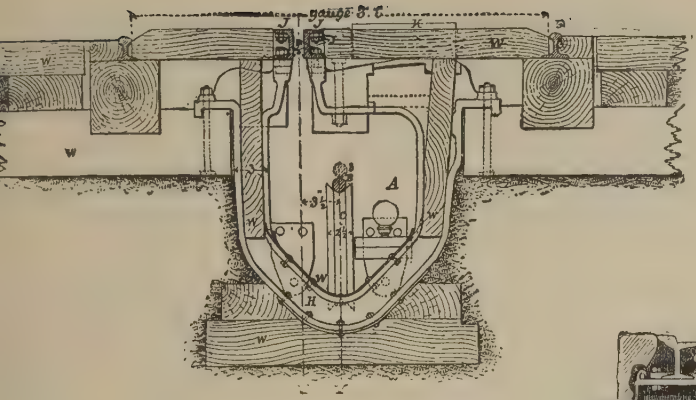


FIG. 137.—ORIGINAL CONSTRUCTION—CLAY STREET (SAN FRANCISCO) LINE.

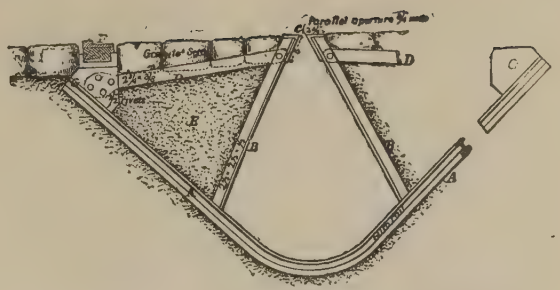


FIG. 138.—ORIGINAL CONSTRUCTION—MARKET STREET LINE.

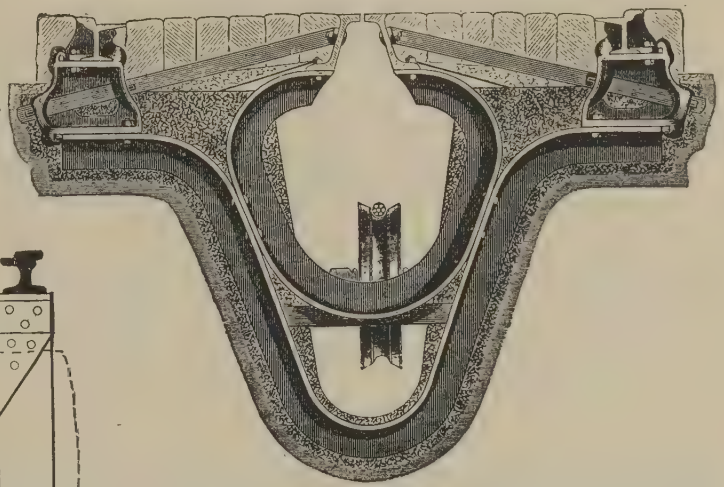


FIG. 140.—ORIGINAL CONSTRUCTION—CHICAGO CITY CABLE RAILWAY—DEPTH OF CONDUIT 36 INCHES.

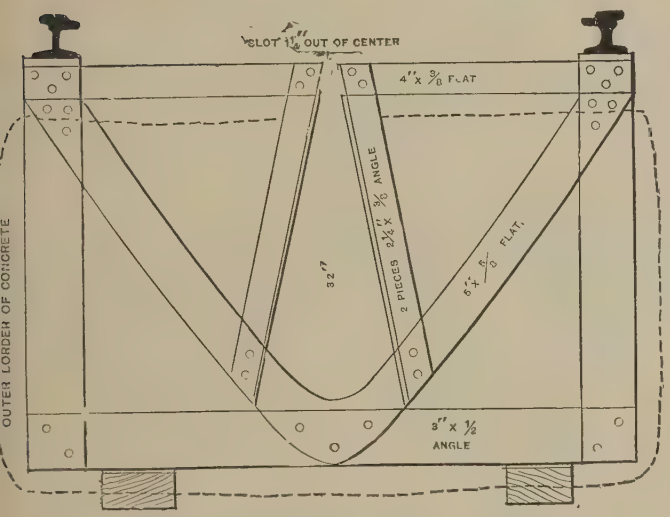


FIG. 141.—YOKE EMPLOYED IN REBUILDING A SAN FRANCISCO LINE.

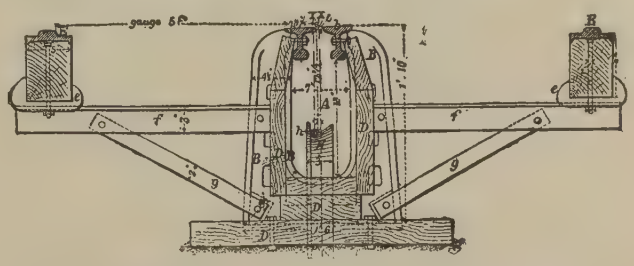


FIG. 139.—ORIGINAL CONSTRUCTION—GEARY STREET LINE.

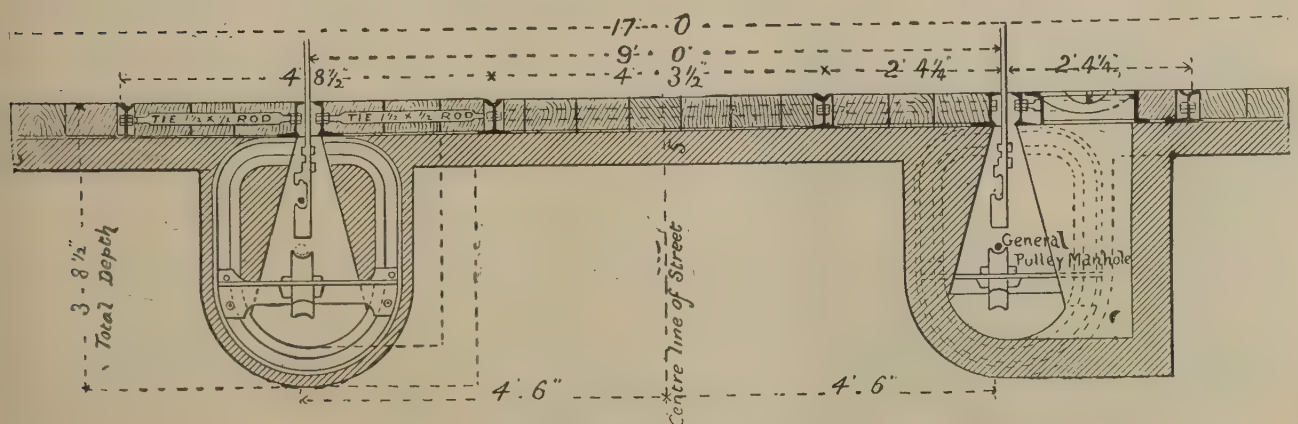


FIG. 142.—CABLE CONSTRUCTION—MELBOURNE, AUSTRALIA.

manhole is reached, where it is removed to the surface. Another form of wrought metal yoke is shown in Fig. 141. This pattern was used in rebuilding one of the old lines in San Francisco, the work being done while the road was in operation. The plan followed was to make an excavation at night when the road had stopped running, and place as many yokes as possible in position, resting on wooden stringers, as shown in same figure, and then connect up the rails. Next day the concrete and pavement were added.

Fig. 142 illustrates the construction of a road in Melbourne, Australia, in which the yokes are made of old rails. Cast iron yokes, however, have come into the most general use in this country, and have been designed in various forms, the idea being to provide great lateral strength with as

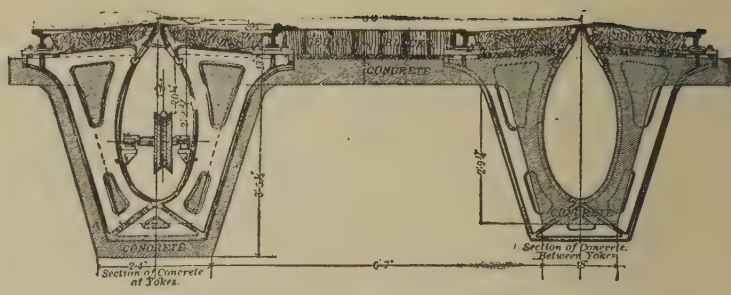


FIG. 143.—KANSAS CITY CABLE RAILWAY CONSTRUCTION.

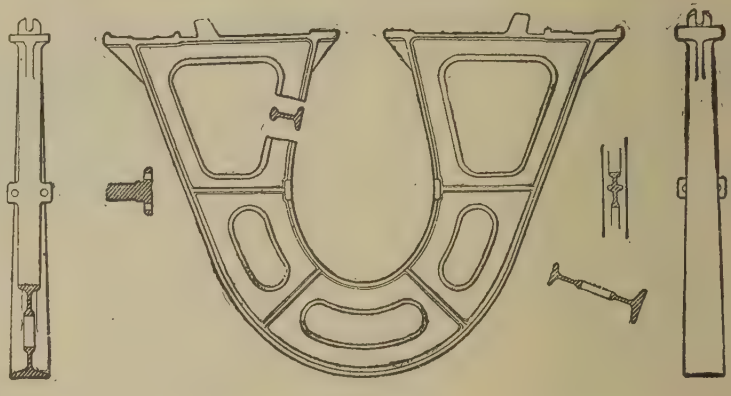
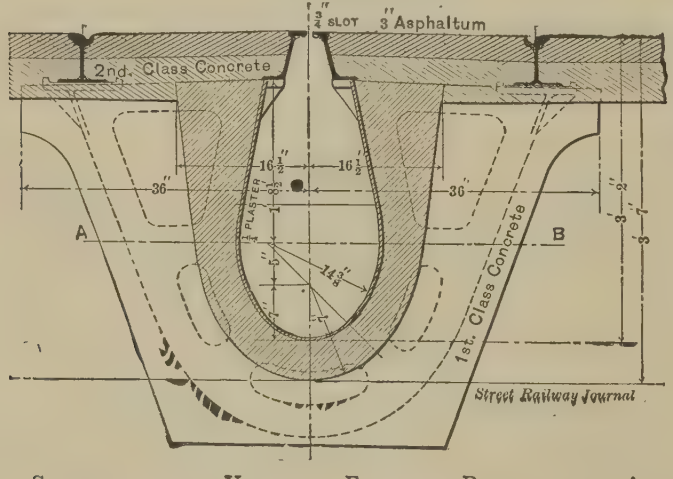
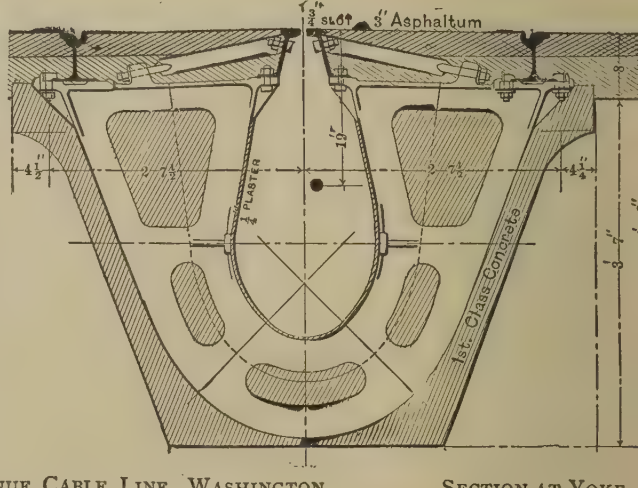


FIG. 144.



SECTION BETWEEN YOKES.



SECTION AT YOKE.

FIG. 145.—PENNSYLVANIA AVENUE CABLE LINE, WASHINGTON.

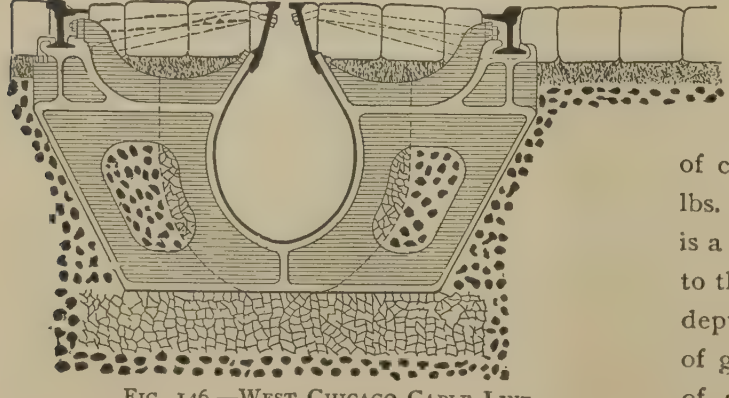


FIG. 146.—WEST CHICAGO CABLE LINE.

little metal as possible, and at the sam time provide suitable lugs to which t anchor the slot rail braces.

Figs. 143 to 149 illustrate various patter of cast iron yokes, weighing from 300 lbs. to 40 lbs. designed for conduits of different depths. Ther is a great diversity of opinion among engineers a to the proper depth of a conduit. In practice th depth varies from nine to forty-two inches, the typ of grip used, the climatic conditions and the dept of gas and water pipes in the streets governing

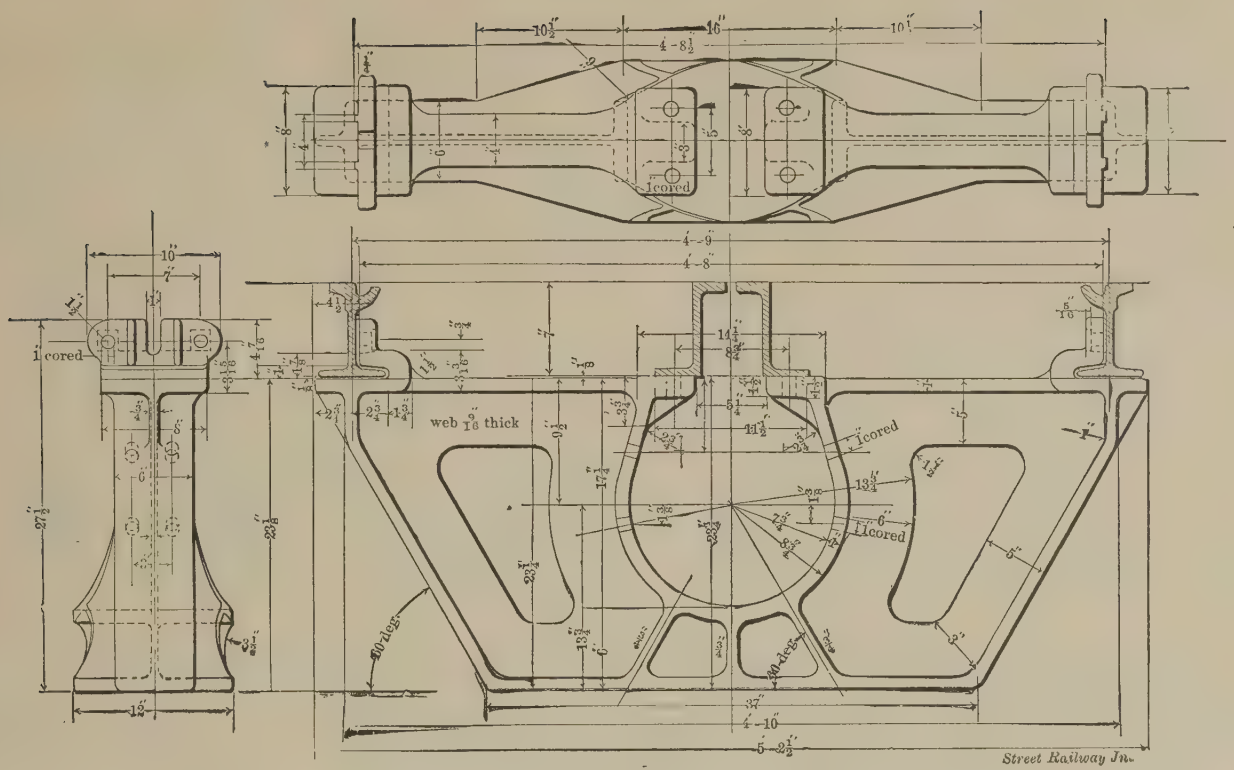


FIG. 147.—YOKE USED ON THE BROADWAY, NEW YORK, CABLE RAILWAY.

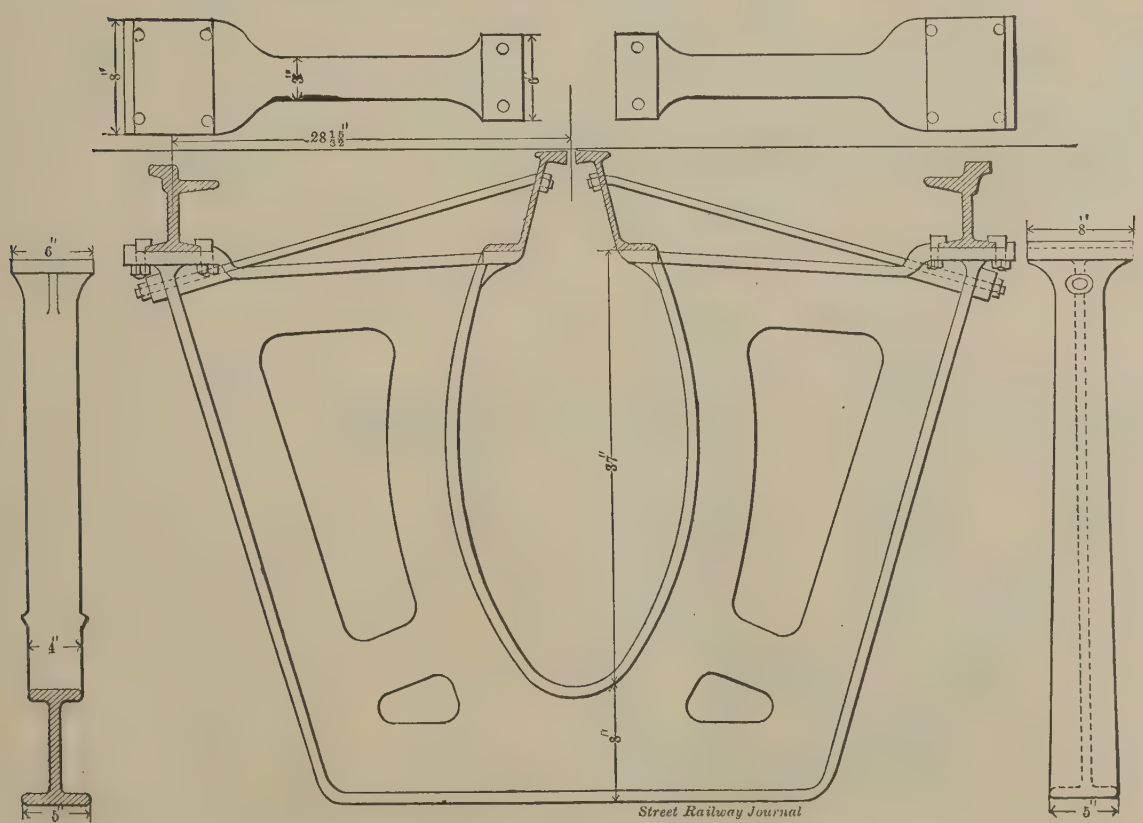


FIG. 149.—CLEVELAND CITY CABLE RAILWAY.—AVERAGE WEIGHT, 360 LBS.

Most engineers prefer to make the conduit deep enough to accommodate the drainage, so that it will not be necessary to sink the pulley vaults or pockets below the level of the conduit. This arrangement avoids the necessity of an auxiliary drain pipe, which, when employed, is liable to become choked by solid matter.

Fig. 150 illustrates a yoke made with both rolled and cast metal, the base being a rolled section in the form of a steel I beam, to which the cast sides are riveted. This yoke gives excellent service, but is an expensive one.

Another composite yoke is illustrated in Fig. 151. This yoke has a body of cast iron, giving it great strength, and has wrought iron arms designed to provide an elastic rail support.

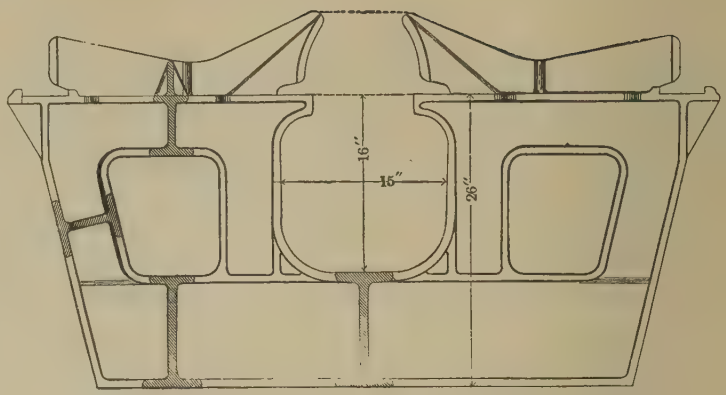


FIG. 148.—YOKE WITH CAST BRACES—THIRD AVENUE, NEW YORK, LINE.

FIG. 148A.—YOKE WITH FLAT STEEL BRACES, KEYED TO LUGS—THIRD AVENUE, NEW YORK, LINE.

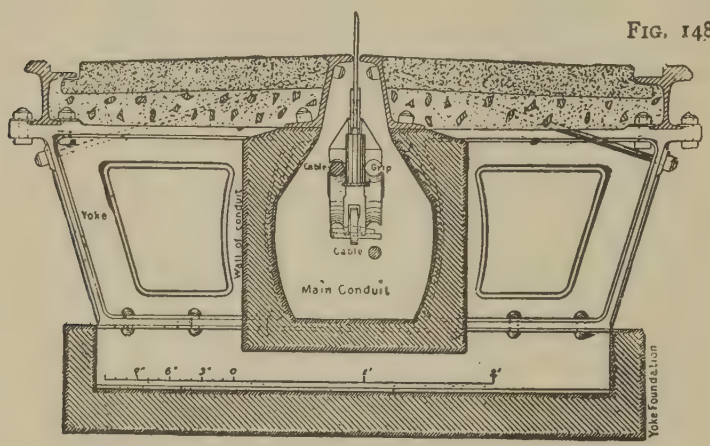


FIG. 150.—ONE HUNDRED AND TWENTY-FIFTH STREET, NEW YORK, CABLE LINE.

Figs. 152 to 158A illustrate different patterns of wrought and cast yokes, each of which has been subject to a reliable test to determine its relative strength and ability to resist side pressure. A record of the test follows each figure and will be found of great value in designing new yokes for any special purpose.

The various methods of bracing the slot rails are clearly shown in the cuts illustrating the yokes, the growing tendency being to arrange the braces so that they may be adjusted without disturbing the pavement to any extent. The different forms of slot rails are also clearly shown in the same figures. Though the slot rails perform very slight service in the running of trains, they are required to have great vertical and lateral strength, and they are made nearly as heavy as the track, in order to support the heavy

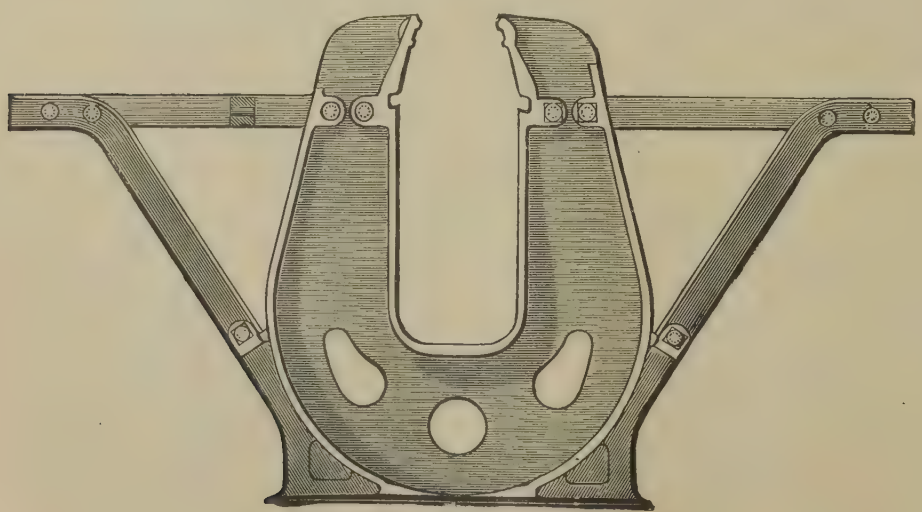


FIG. 151.—COMPOSITE YOKE.

TEST OF ROLLED STEEL CABLE YOKE, GRAND AVENUE CABLE CO., KANSAS CITY, MO.

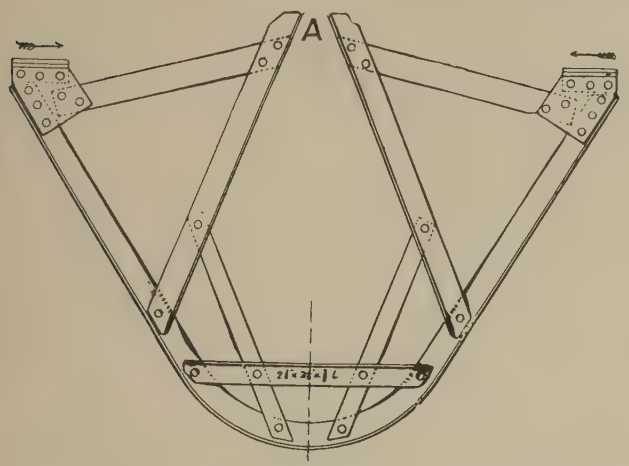


FIG. 152.—YOKE ON GRAND AVENUE CABLE LINE, KANSAS CITY.

Load lbs.	Deflection. Inches.	Permanent Deflection. Inches.
100	.02	.....
200	.045	.....
500	.125	.00
1000	.27	.03
1500	.44	.....
2000	.62	.....
3000	.93	.....

Force applied as indicated by arrows. Approachment of points A, A, measured and called Deflection.

TEST OF CABLE RAILWAY YOKE, ST. LOUIS CABLE & WESTERN RAILWAY.

Load lbs.	Deflection. Inches.	Permanent Deflection. Inches.
200	.05	.....
500	.115	.....
800	.185	.....
4000	1.01	.16
4800	2.13	.....

Compression applied as indicated by arrows in sketch. Distance A measured and its diminution called Deflection. Weight of rail, knee castings, and chairs, 241 lbs.

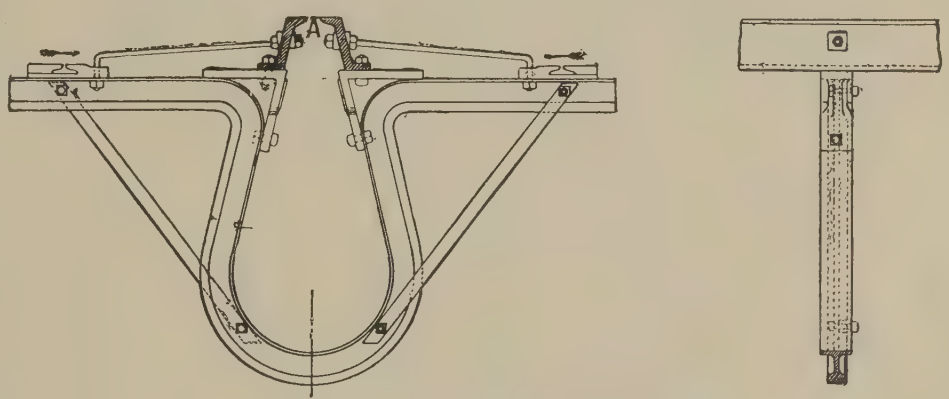


FIG. 153.—ST. LOUIS CAB EL& WESTERN LINE.

TEST OF CABLE RAILWAY YOKE, CHICAGO CITY RAILWAY.

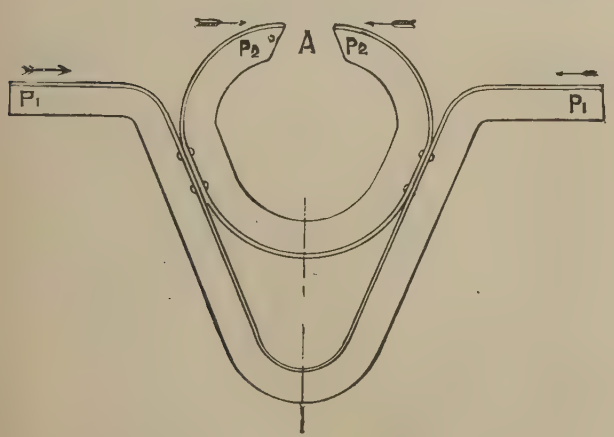


FIG. 154.—CHICAGO CITY CABLE RAILWAY.

	P_1		P_2	
Load lbs.	Deflection. Inches.	Permanent Deflection. Inches.	Deflection. Inches.	Permanent Deflection. Inches.
200	.01	.....	.02	.....
400	.02	.....	.04	.....
1000	.045	.00	.12	.00
1600	.075	.....	.195	.....
2000	.09	.00	.27	.025
3000	.145	.....	.515	.17

Two tests were made. First pressure was applied as indicated by arrows P_1 P_1. After applying 3,000 lbs. load this way, pressure was applied at P_2 P_2. Weight of yoke 164½ lbs. Distance A gauged and its diminution is called Deflection.

TEST OF CAST IRON YOKE, NORTH CHICAGO CABLE RAILWAY.

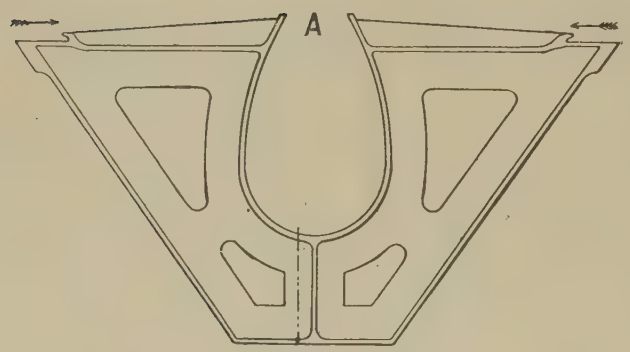


FIG. 155.—NORTH CHICAGO CABLE YOKE.

Load lbs.	Deflection. Inches.	Permanent Deflection. Inches.
400	.015	.....
1000	.03	.00
2000	.055	.00
3000	.085	.00
4000	.12	.005
5000	.155	.01
10000	.355	.04

Pressure applied as indicated by arrows in sketch. Distance A gauged and its diminution is called Deflection in report. Weight 416½ lbs. Casting not broken.

TEST OF CAST IRON CABLE YOKE, KANSAS CITY PATTERN.

Load lbs.	Deflection. Inches.	Permanent Deflection. Inches.
200	.01	.....
1000	.04	.00
1400	.06	.....
2000	.085	.01
3000	.15	.....
4000	.20	.01
8000	.44	.04
10000	.56	.05

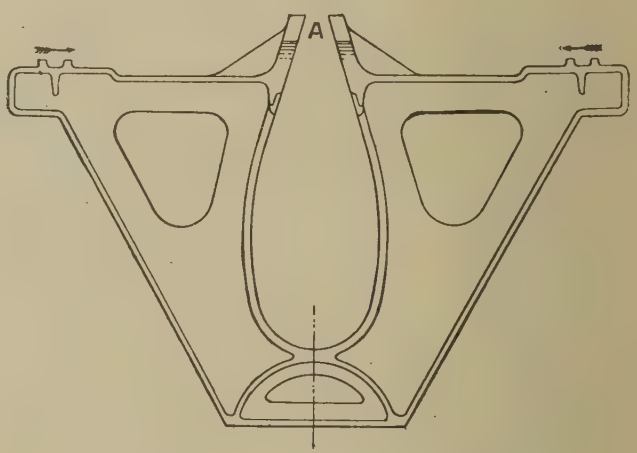
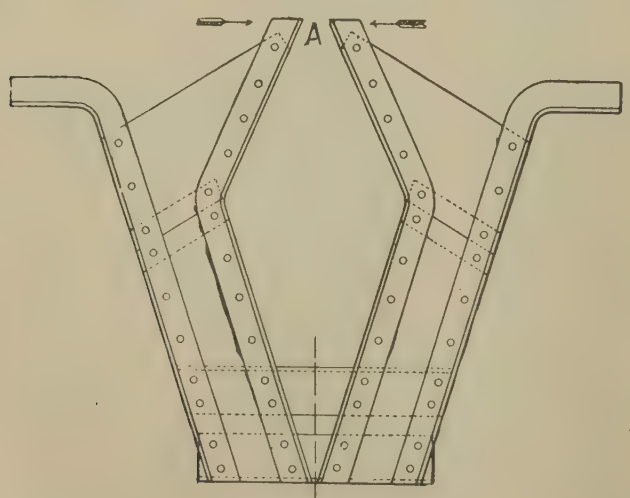


FIG. 156.—KANSAS CITY PATTERN OF YOKE.

Pressure applied as indicated by arrows in sketch. Distance A gauged and its diminution measured, which is called Deflection in report Weight of casting 380 lbs. Casting not broken.



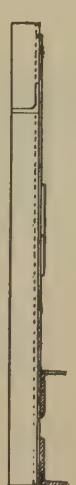


FIG. 157.—JOHNSON COMPANY'S STEEL YOKE.
Plates one-quarter inch thick.

Load lbs.	Closure. Inches.	Permanent Closure. Inches.
200	.01	.....
400	.02	.....
1000	.065	.....
1600	.10	.....
2000	.125	.....
2400	.145	.....
3000	.185	.00
4000	.255	.....
5000	.355	.....
6000	.46	.08
7500	.....	.28

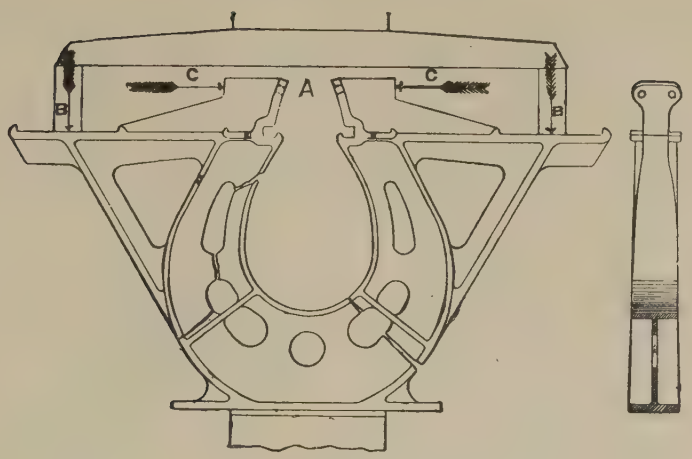


FIG. 158.—PROPOSED YOKE.

COPY OF OFFICIAL TEST MADE AT WATERTOWN ARSENAL LABORATORY WITH TWO YOKES, CALLED RESPECTIVELY NO. 1 AND NO. 2.

LOADED IN DIRECTION OF ARROWS B B.				LOADED IN DIRECTION OF ARROWS C C.			
Applied Load.	Movement at A.		Remarks.	Applied load.	Movement at A.		Remarks.
	Yoke No 1. Inch.	Yoke No. 2. Inch.			Yoke No. 1 Inch.	Yoke No 2. Inch.	
200	0	.0		200	.0	.0	
600	.0017	.0020		400	.0040	.....	
1000	.0017	.0050		600	.0078	.0080	
1400	.0057	.0065		800	.0112	.....	
1800	.0088	.0084		1000	.0153	.0140	
2200	.0100	.0090		1200	.0202	.....	
2600	.0198	.0132		1400	.0230	.0183	
3000	.0241	.0160		1600	.0270	.....	
3500	.0217	.0170		1800	.0309	.0270	
4000	.0275	.0220		2000	.0342	.....	
4500	.0300	.0220		2200	.0387	.0336	
5000	.0447	.0220		2400	.0425	.....	
6000	.0488	.0290		2600	.0459	.0380	
7000	.0547	.0370		2800	.0490	.....	
8000	.0618	.0420		3000	.0538	.0440	
10000	.0747	.0520		200	.0068	.....	Permanent set of No. 1.
14000	.1027	.0765		3000	.0559	.0440	
16000	.1157	.0875		3500	.0645	.....	
18000	.1290	.1040		4000	.0745	.0625	
200	.0157	.0120	Permanent set.	4500	.0847	.0710	
8000	.....	.....	No. 2 retained under	5000	.0945	.0788	
18000	Yoke re-	.1022	this load fifteen hours.	5500	.1050	.0900	
20000	moved from	.1110		6000	.1160	.0990	
22000	machine and	.1230		6500	.1270	.1060	
24000	auxiliary bar	.1370		7000	.1385	.1162	
26000	at top remov-	.1540		7500	.1495	.1270	
28000	ed and yoke	.1640		8000	.1617	.1364	
30000	replaced in	.1805		9000	.1847	.1560	
32000	machine and	.1951		10000	.2060	.1720	Permanent set here
34000	pressure ap-	.2070		12000	.2549	Yoke re-	of No. 2. .0198.
35000	plied in di-	.2140		14000	.3050	moved from	
37000	rection of ar-	.2350		16000	.3566	machine and	
40000	rows C C.	.2700		18000	.4120	auxiliary bar	
42000	.....	.....	Net Strength—Frac-	20000	.4700	at top ap-	
.....	.....	.....	ture sound and of	22000	.5350	plied, replac-	Snapping Sounds.
.....	.....	.....	strong granular ap-	23000	.57	ed in ma-	
.....	.....	.....	pearance.	24000	.61	chine and	
.....	.....	.....		24900	.....	pressure ap-	Net strength—Frac-
.....	.....	.....		.....	.....	plied in di-	ture in a direction near
.....	.....	.....		.....	.....	rection of ar-	base of yoke.
.....	.....	.....		.....	.....	rows B B.	.....

street traffic and preserve the slot to an exact width, which is usually about three-fourths of an inch.

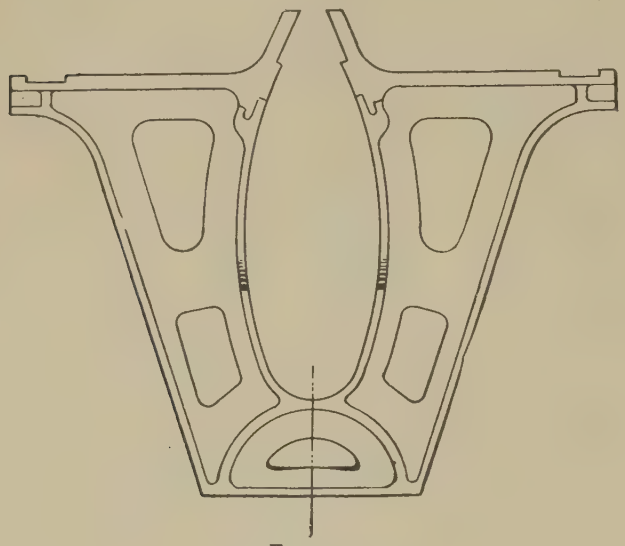


FIG. 157A.
Weight 414½ lbs.

Load lbs.	Closure. Inches.	Permanent Closure. Inches.
200	.01	.....
800	.055	.....
1000	.07	.....
1200	.085	.....
2000	.15	.005
2600	.20	.....
3000	.235	.015

Fig. 159 illustrates a somewhat different method of bracing the slot rail, in which it will be

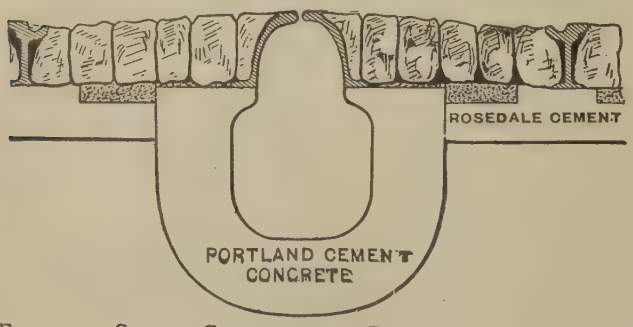


FIG. 159.—STREET CONSTRUCTION BETWEEN YOKES—THIRD AVENUE, NEW YORK, CABLE LINE.

noted, a flat brace is employed, having two bolts by which it is attached to the slot rail; this is to prevent the tilting of the slot rail, as sometimes happens when the tie rod is attached to the middle of the rail. The same construction also provides for an adjustable slot, as the space between the slot rail and the arched support can be filled with asphalt or some material that can be melted, and the slot widened should it become necessary. The object in this particular construction, of giving the slot

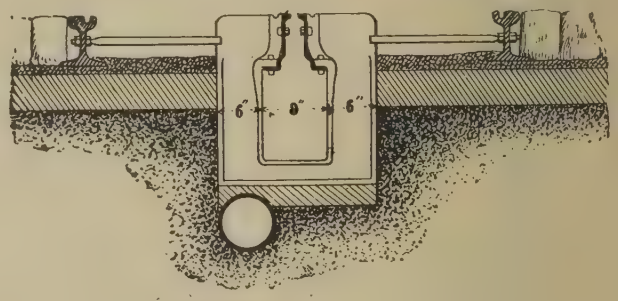


FIG. 160.—EDINBURGH NORTHERN TRAMWAY.

rails so wide an arch is to provide for running the grip jaws very near the surface, thus allowing for a more shallow conduit, rendered necessary by the presence of innumerable pipes in the streets.

Fig. 160 illustrates a method of construction adopted by the Edinburgh Northern Cable Tramway of Scotland, that can be built for a moderate cost. The cast iron yokes weigh 135 lbs. each. They have a web one inch thick and are spaced three feet six inches apart. The slot rails are of steel and weigh thirty-nine pounds per yard. They are of peculiar design and are intended to lessen the cost of construction by reducing the depth of tube and providing a guard for the grip on curves. This is done by setting back the lower member, which forms a lower vertical plane, against which a

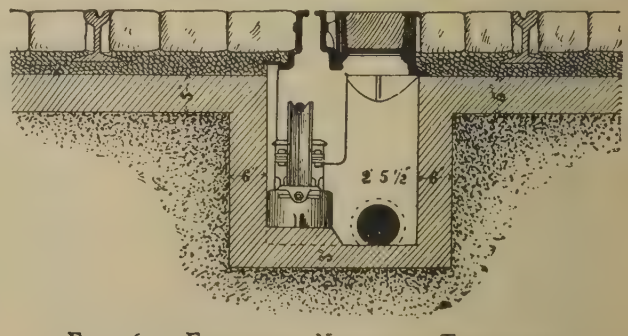


FIG. 161.—EDINBURGH NORTHERN TRAMWAY.

friction roller on the grip rests in rounding curves. The conduit is nineteen inches deep from the surface and nine and a half inches wide. The pulley vaults are connected with a six inch drain pipe.

The inner faces of the slot rails should be vertical to prevent horseshoe calks from becoming wedged in the slot. The practice of rounding the edges is objectionable for the reason that it becomes a trap for horse shoes. In case the slot closes a trifle from frost pressure or heavy traffic, it is sometimes necessary to force it open by means of iron wedges driven in with heavy hammers; and in some cases it has been found necessary to chip off the inner surfaces of the slot rails by means of a cold chisel.

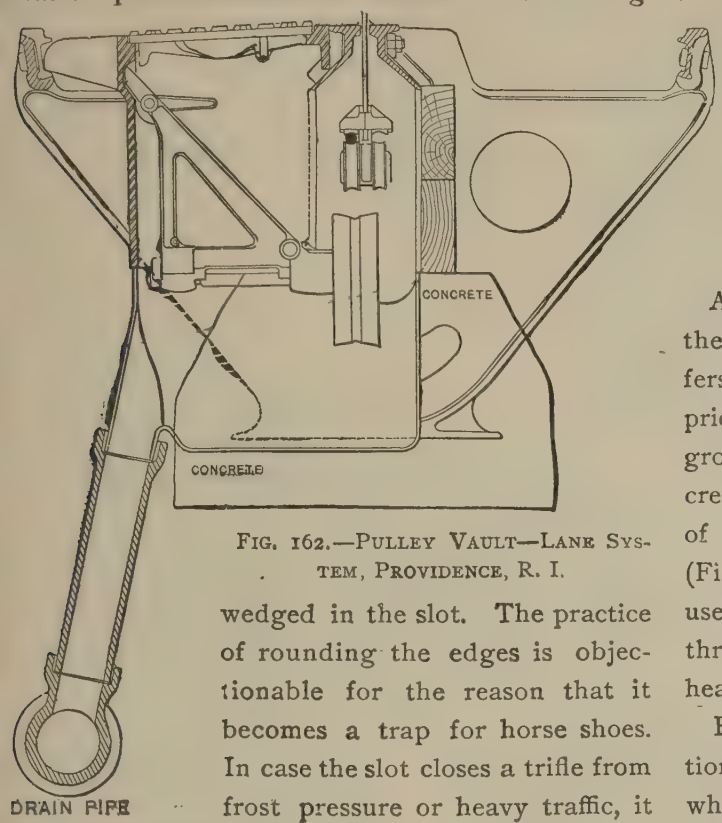


FIG. 162.—PULLEY VAULT—LANE SYSTEM, PROVIDENCE, R. I.

Roads have been constructed with the slot rail two inches higher than the track rails. See Fig. 143. This construction is objectionable where it is necessary to operate cars by horses over the same line, as the slanting pavement makes an unsuitable track for horses, and it is also difficult for other lines to cross such a construction. It is desirable, however, to have the slot rail elevated from a half inch to an inch above the track rail to prevent water and dirt from entering the slot.

In the early construction, as before stated, the walls of the tube or conduit were made of plank. Concrete, however, has been generally substituted in later construction, with the exception of a few lines which employ both concrete and wood, as shown in Fig. 162, the foundation being of concrete and the sides of four inch creosoted plank. In this system the conduit is reduced in depth to twenty-one inches and the drainage is made independent instead of along the bottom. With this construction, it is claimed, a road can be built at less cost than those with a deep conduit, but there is a good deal of objection to the shallow conduit construction, except in favored localities.

As to the quantity of concrete to be used and the thickness of the walls of the tube, practice differs. In localities where, on account of the high price of iron, light steel yokes are used, it is a growing practice to use large quantities of concrete, and to depend entirely upon the strength of the concrete walls to resist the side pressure. (Fig. 141.) In other localities very heavy yokes are used, and the concrete side walls are made only three or four inches thick, but, of course, with a heavy foundation.

Figs. 163 and 164 illustrate a type of construction known as the Isaacs' concrete road bed, in which no yokes are employed, the tube being constructed entirely of concrete. The conduit is twenty-four inches deep. The walls on the bottom are about fourteen inches thick, and the lateral thickness at the top is about two feet. It is claimed that on lines constructed in this manner the ability

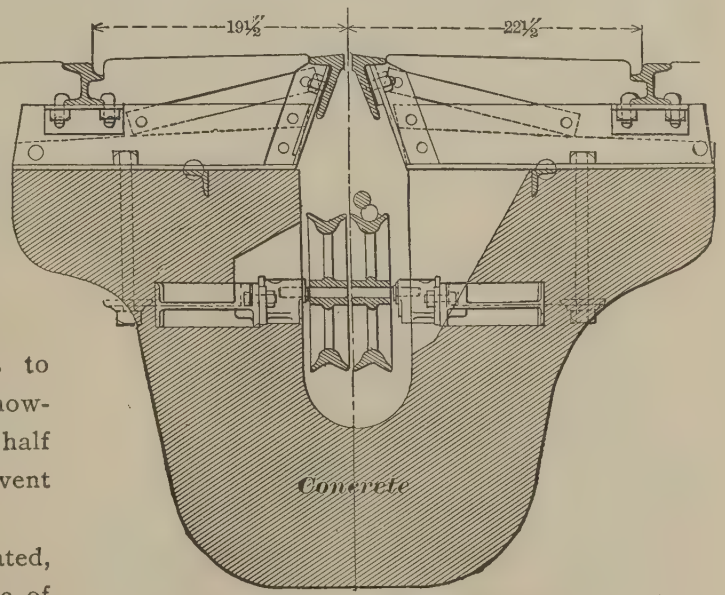


FIG. 163.—LIGHT SECTION—ISAACS' CONCRETE ROAD BED, OAKLAND, CAL.

of the concrete to withstand the action of external forces tending to slot closure is equal to that of iron yokes, and that there is a saving of from $15,000 to $20,000 per mile in cost over yoke construction. Tests show that concrete, made of the best materials, properly mixed, is capable, when set, of standing a compressive strain of 200 tons to the square foot, and a tensile strain of fifteen tons.

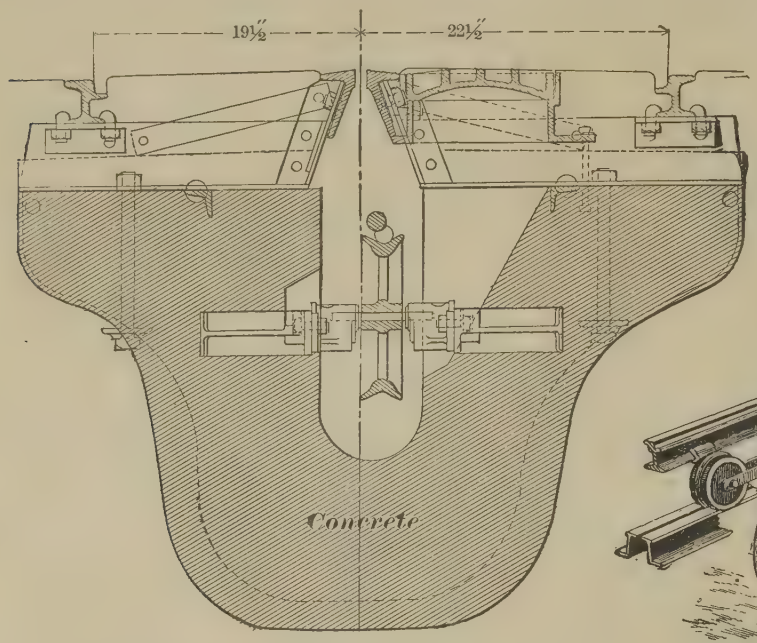


FIG. 164.—HEAVY SECTION—ISAACS' CONSTRUCTION.

Following the steps of ordinary construction, the yokes having been arranged in the trench, the slot and track rails are next bolted in place, when the entire iron work is moved to line and grade, and is supported in place by being suspended from temporary cross timbers, which rest on the sides of the trench. The concrete is next put in and tamped solid under the yokes and around the wooden folding forms or templets, which are made in two pieces and commonly hinged together at the bottom (Fig. 165), and when placed in position, and slightly wedged apart, have the exact form of the conduit through which the cable is to run. These forms are made in sections of four or five feet, and as soon as the wall has set the wedge is removed when the forms collapse and are readily moved further on by means of hooks introduced through the slot, or by being suspended from a trolley running on the slot rail. (Fig. 166.)

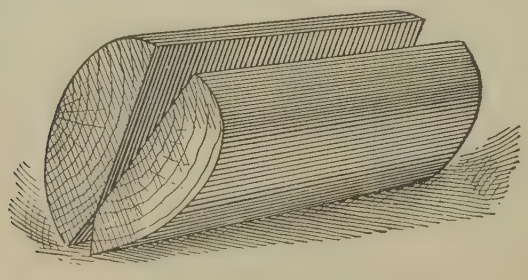


FIG. 165.—FOLDING FORM.

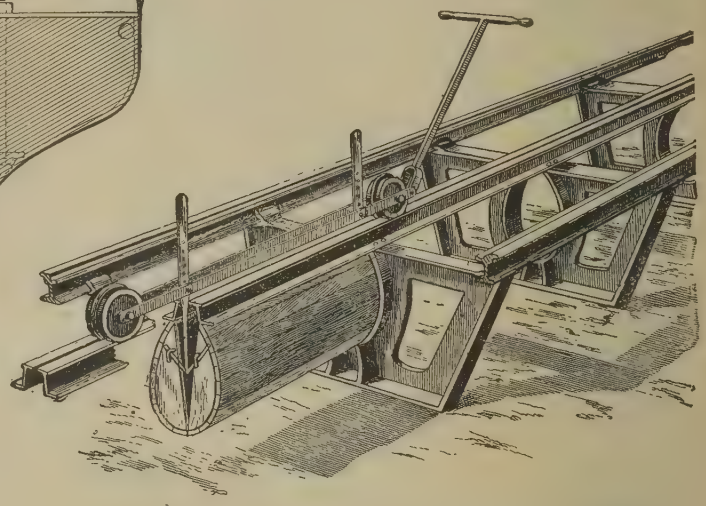


FIG. 166.—FOLDING FORM WITH TROLLEY SUPPORT.

Some engineers prefer to provide concrete foundations or piers for the yokes, and place them to grade before attaching the rails. This practice is followed usually where the streets are narrow, in order that the street traffic may not be interrupted.

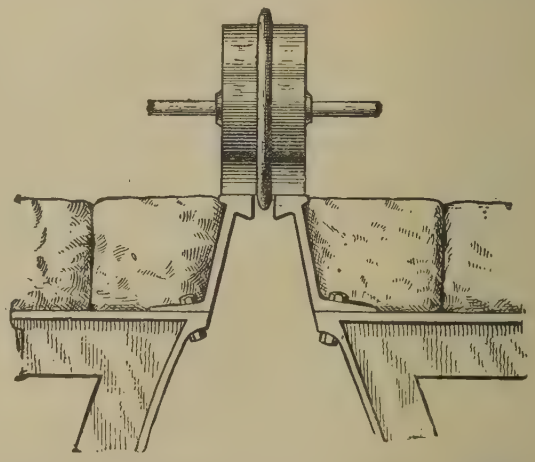


FIG. 166A.—ENLARGED VIEW OF TROLLEY WHEEL.

Instead of employing wooden templets to form a backing for the concrete, the practice is quite com-

mon of employing oblong steel tubes made of rolled plates, about one-fourth of an inch in thickness, which are bolted to the yokes and form a lining to the conduit. This arrangement is shown in Figs. 146 and 174. The dotted lines show the thickness of the concrete walls. Engineers do not agree as to the advantage gained by the use of the steel lining. The metal corrodes, it is claimed, and forms no support for the concrete after it is set. Others hold that there is a saving of time in construction by the use of the lining, for it is not necessary to wait for the concrete to set before beginning a new section, as is the case when forms are employed. This saving, however, would seem to be balanced by the extra time required for fitting the lining and bolting the sections in place. The materials—best Portland cement, one part; sand, three parts; broken stone, five parts—of which the concrete forming the tunnel is composed, may be mixed upon a platform of boards or in a box, and water being added, it may be thrown in place from the box by means of shovels and then firmly tamped. This work is more expeditiously performed, however, by means of concrete mixers, types of which are shown in Figs. 167

FIG. 167.—CONCRETE MIXER.

and 168, but in quality this is not considered equal to that mixed by hand. The first of these machines

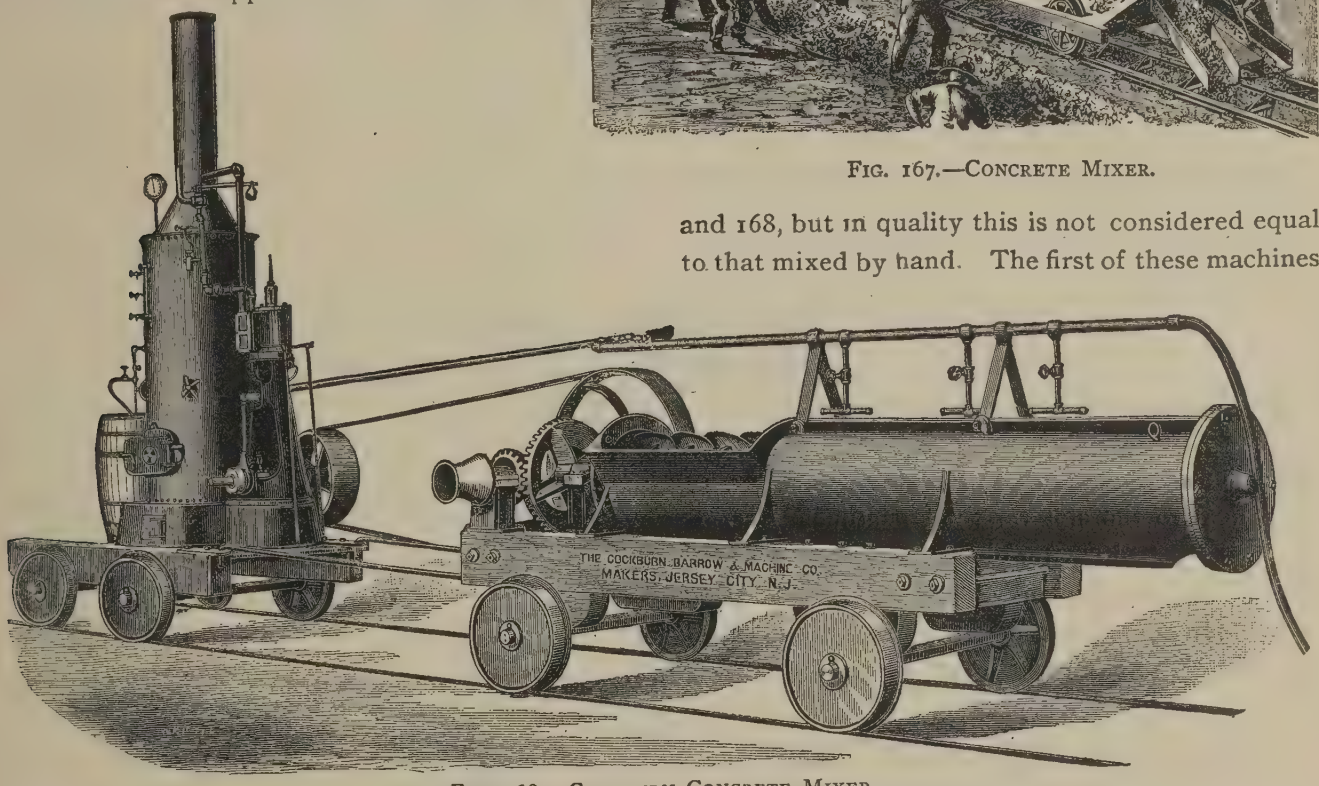


FIG. 168.—COCKBURN CONCRETE MIXER.

consists of a long box having a spiral conveyor running from end to end, which is revolved rapidly

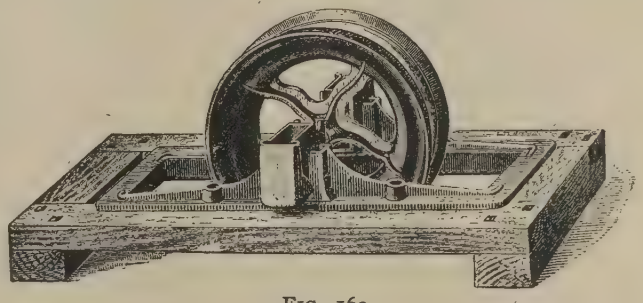


FIG. 169.

by a stationary engine, and discharges the mixture into the proper place between the tracks, water being added from an overhead supply pipe. The en-

tire mechanism being mounted upon wheels, it is readily moved ahead on the track as a given por-

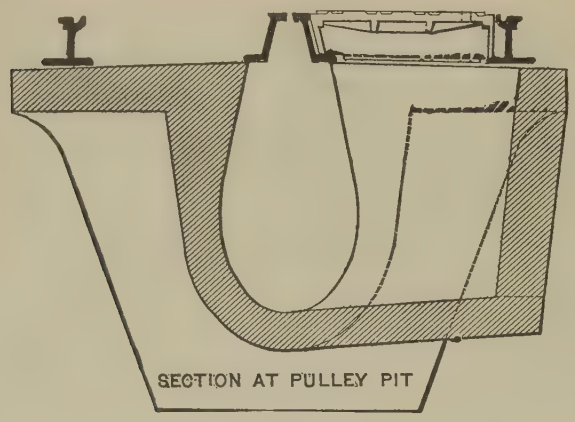


FIG. 170.

tion of the trench is filled up. The second is made with an iron tubular casting open on the top, and the spiral has paddles set in opposite directions, the greater number pushing toward the delivery, so that ultimately the material finds its way out.

Sand is then placed upon the concrete, forming a bed for the pavement. The top of the conduit next to the slot rails is sometimes formed by steel paving plates, extending from yoke to yoke, and resting with one side on the concrete and the other on the lower edge of the slot rail, as shown in Fig. 140.

The patterns of carrying pulleys and the methods of mounting them in the conduit vary about as much as the different types of yokes. They are usually placed from thirty to forty feet apart except on the crowns of hills where the grade suddenly changes; and here they should be placed very close together to support the down pull of the cable, or a forty inch crown sheave may be substituted. Fig. 169 is an illustration of a common cast iron groove pulley about twelve inches in diameter, mounted with its journal boxes on an iron frame, which in turn rests on a wooden frame, and being placed in the conduit is supported between the two yokes. (Fig. 140.)

In most systems, however, a chamber or pulley vault is provided in the side of the conduit, having a manhole with cover flush with the pavement, through which access is had to the pulley for oiling, inspection and renewal, and through which any accumulation of dirt and snow may be removed. This is shown in Figs. 170, 171, 172. In the construction of some lines a very large pulley vault is provided, made of cast iron plates or with concrete walls, sometimes four feet long and four feet deep. In the side of this the carrying pulley is mounted on a suitable frame, while the iron cover full length of the vault has in the middle a small hand hole with separate cover through which the bearings may be oiled. One objection to large manhole covers is the difficulty of fitting them accurately to the frame so that they will not tilt and rattle when vehicles pass over them. Peo-

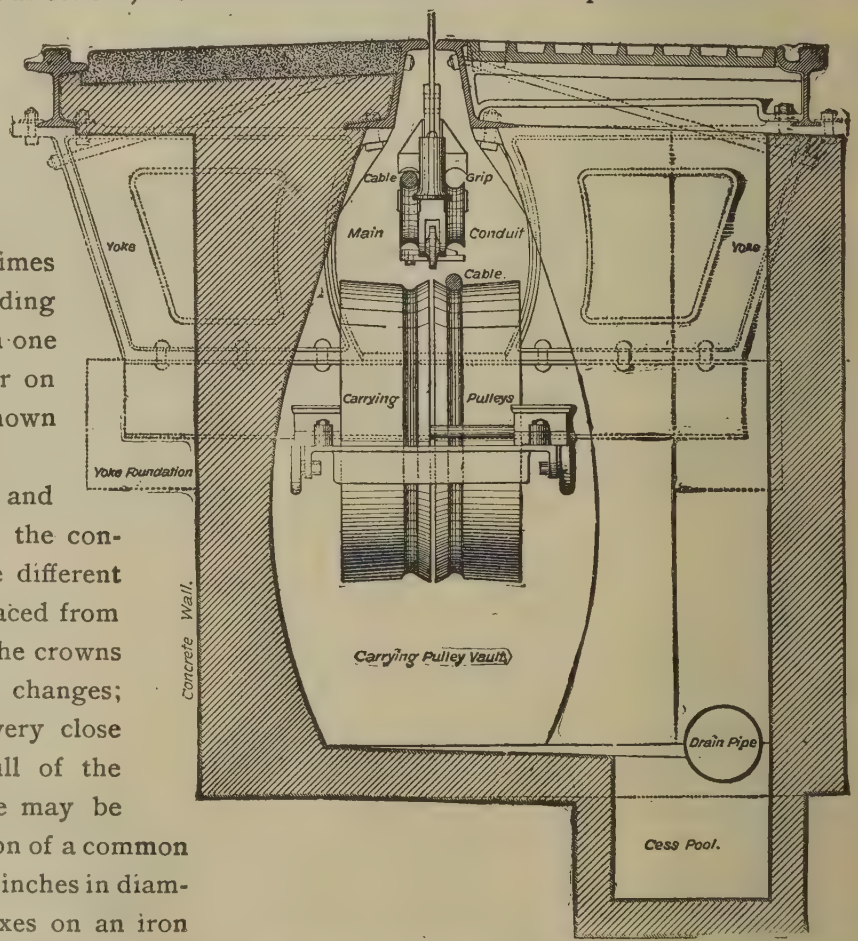


FIG. 171.—PULLEY VAULT FOR DUPLICATE CABLES, TENTH AVENUE, NEW YORK LINE.

ple living along lines constructed with the large covers, sometimes complain of being disturbed at

night by the sounds produced in the manner above described. Fig. 162 illustrates a very compact

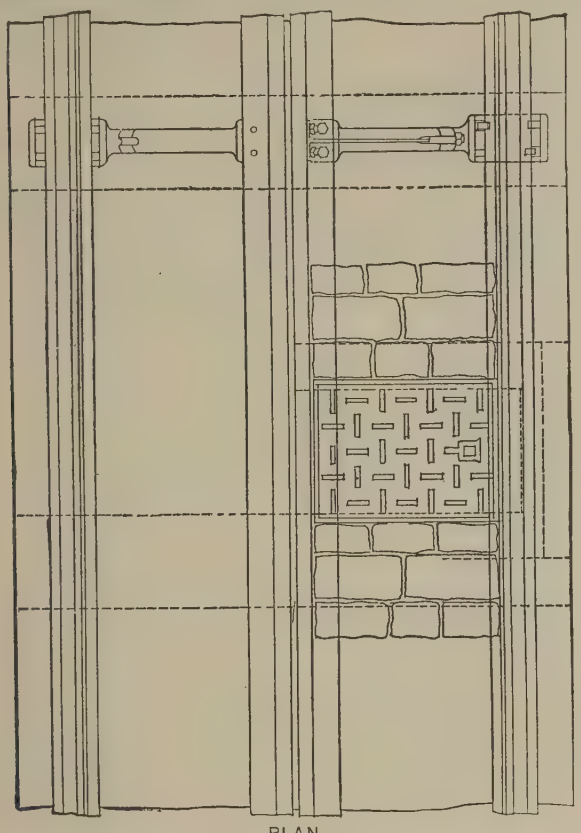


FIG. 172.—SURFACE OF STREET, SHOWING MANHOLE COVER.

pulley vault of cast iron, circular in form, and only about eighteen inches in diameter. With this construction the pulley is mounted on an adjustable triangular frame, overhanging, both the bearings being on one side. The frame is held in place by a cam lever, and by releasing the lever the frame and pulley may be lifted out at the manhole. In a double track road the opposite vaults are sometimes connected by a cross vault with one manhole between the tracks, as illustrated by Figs. 173.

Figs. 150, 171, 173, 174 are designs of yoke, conduit vault and cover for a duplicate cable system in which two ropes are operated in the same conduit, each entirely independent of the other, and so

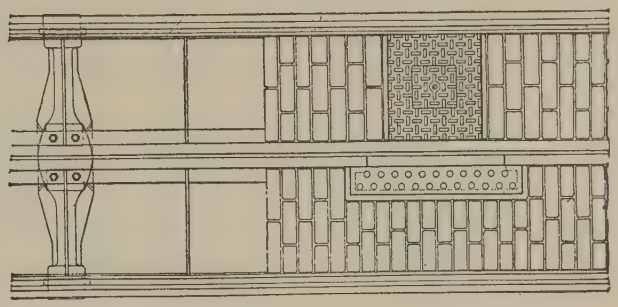


FIG. 172A.—MANHOLE AND GRIP HATCH COVER—BROADWAY, NEW YORK, LINE.

arranged at the driving station that if one rope or its machinery should become disabled the second rope can be brought into immediate use. By this arrangement a road can be operated continuously day and night, and ample time can be had for inspection and for making needed repairs to the idle cable and machinery. In this system the carrying pulleys are mounted in pairs, the grooves supporting the cables being slightly on each side of the slot. (Figs. 175 and 176.) These particular wheels are made with six light, round, wrought iron arms which render them light and durable. It is custom-

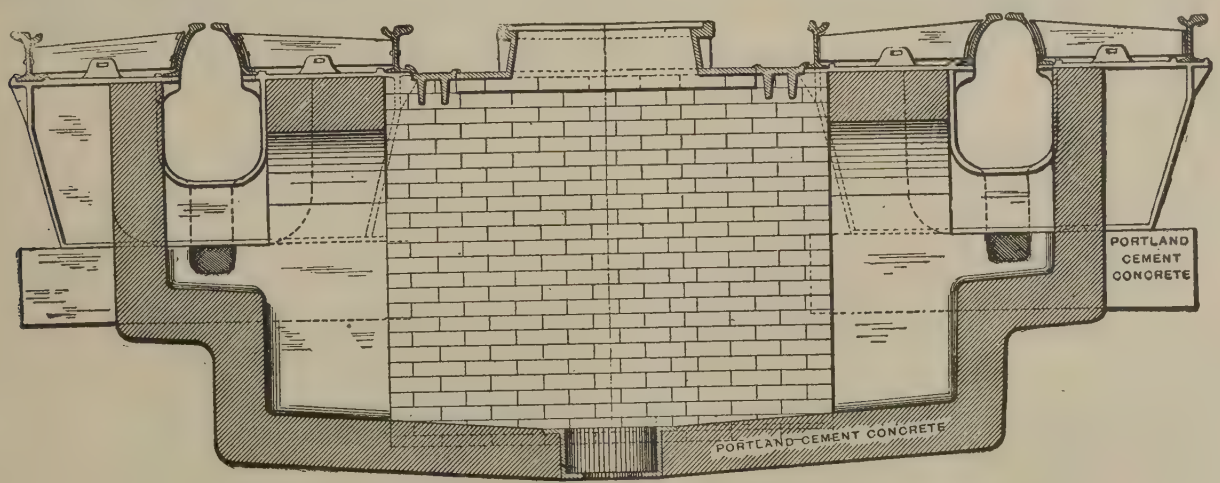


FIG. 173.—CROSS VAULT WITH SINGLE MANHOLE—THIRD AVENUE, NEW YORK, LINE.

ary, when it is found necessary to change from one cable to another in the duplicate system, to start up the idle cable and keep both in operation long enough for all the cars to reach the terminals of the line, and, by changing a single sheave at the end of the line, each car as it starts on the return trip will be transferred to the other rope without any attention on the part of the gripman.

There are numerous patterns of carrying pulleys in use, varying in diameter from nine to twenty-two inches, some made of solid cast iron, others of a combination of wrought iron and cast iron as above. Another pattern of the latter is shown in Fig. 177 which represents a pulley fourteen inches in diameter, having wrought spokes, cast hub, and a cast rim chilled through. this type of pulley is used the spindle should be pressed in, otherwise it is liable to work loose, rendering it necessary to remove the pulley before

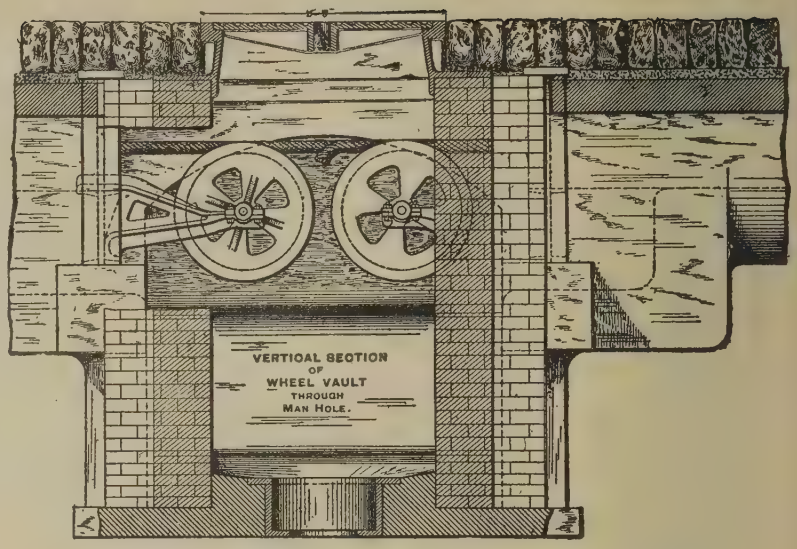


FIG. 173A.—THIRD AVENUE, NEW YORK, CABLE LINE.

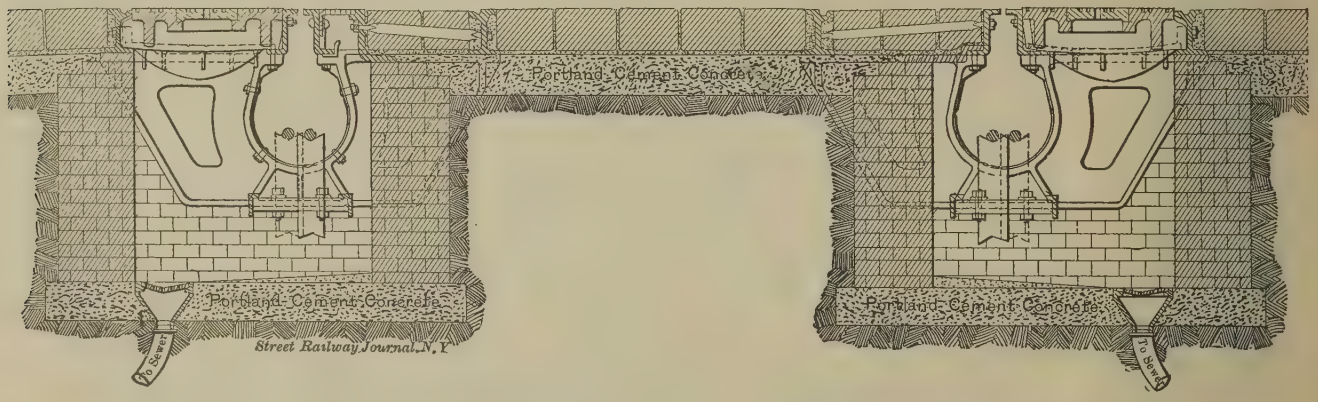


FIG. 174.—SHEAVE PITS AND GRIP HATCH, BROADWAY, NEW YORK, CABLE LINE.

The spindle is of hardened steel and the bearings are turned down to eleven sixteenths of an inch. The weight is about twenty-two pounds. In case it is worn out. Fig. 178 illustrates an adjustable chilled rim pulley, in which the rim may be renewed when worn. Another adjustable pulley having three parts, is shown in Fig. 179. The parts of sectional pulleys require to be accurately fitted to prevent their working loose and rattling under the peculiar forces acting upon them.

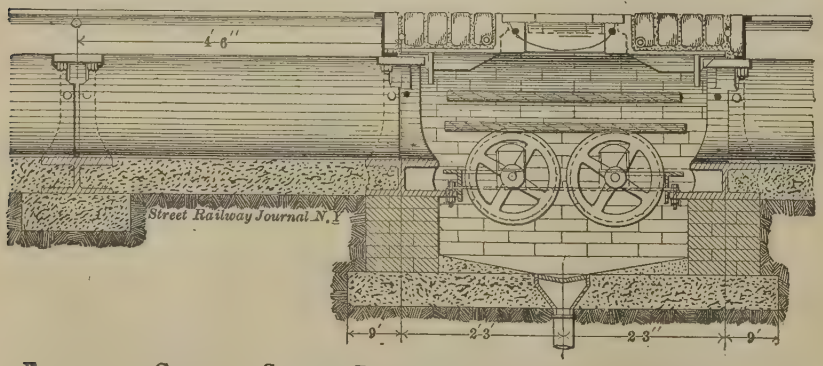


FIG. 174A.—CONDUIT, SHEAVE PIT AND GRIP HATCH—BROADWAY, NEW YORK. CABLE LINE.

Fig. 180 illustrates a cast pulley with chilled face. Chilled rim pulleys will last from six to eight times as long as ordinary cast pulleys. The grooves of chilled pulleys should be smoothed up on an emery wheel be-

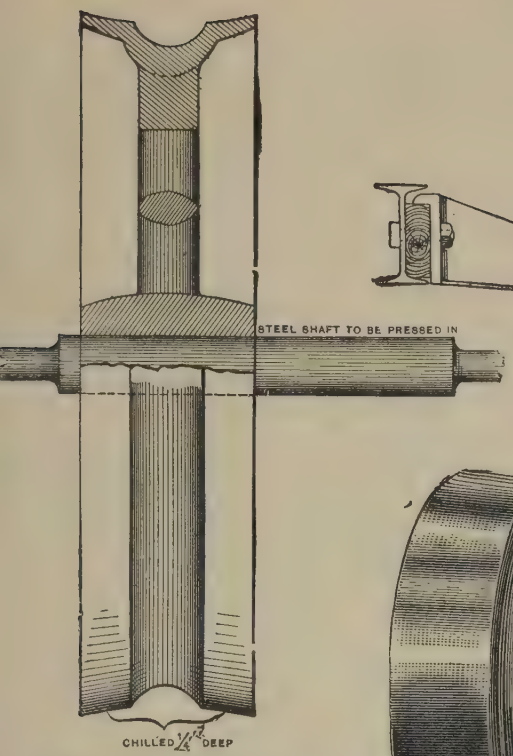


FIG. 180.—CHILLED CAST PULLEY.

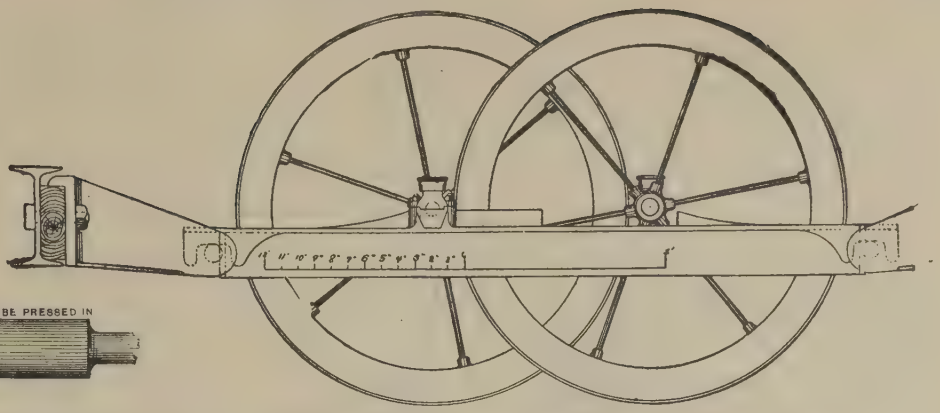


FIG. 175.—CARRYING PULLEYS FOR DUPLICATE CABLES.

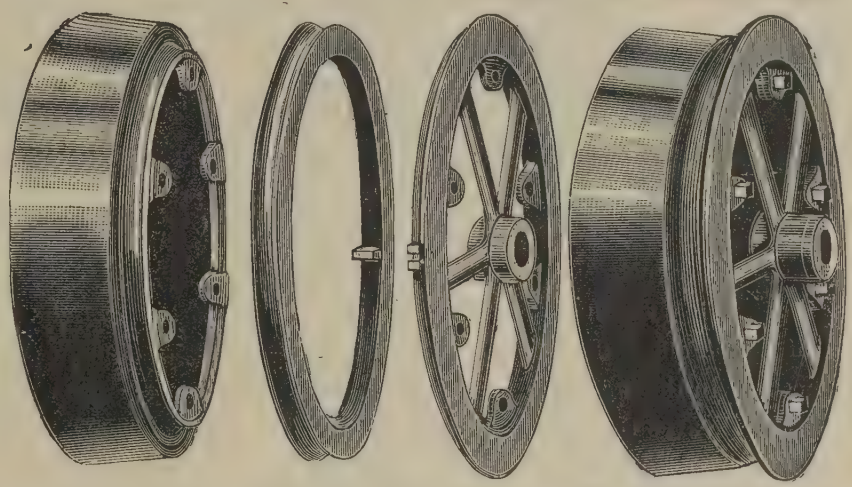


FIG. 179.—THREE PART ADJUSTABLE PULLEY.

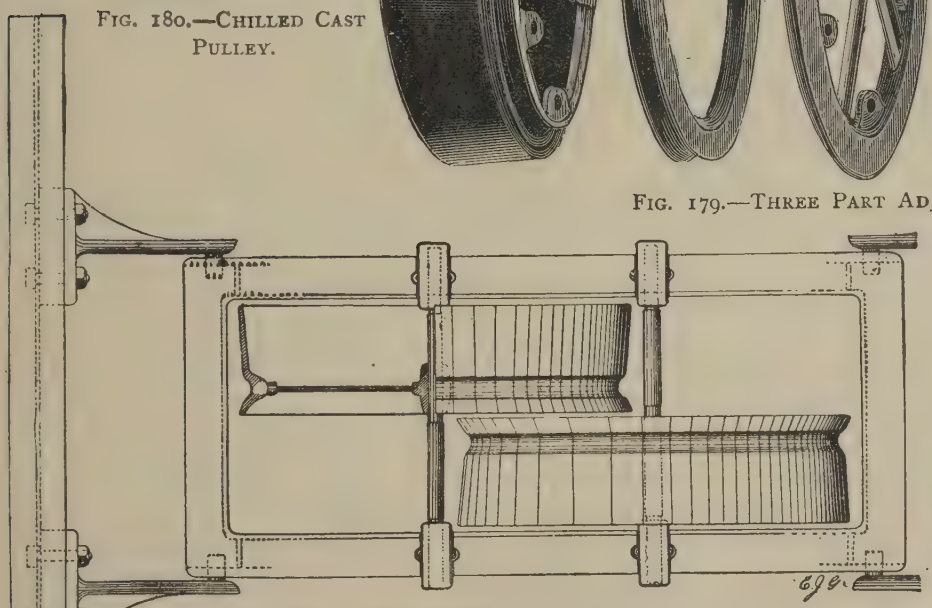
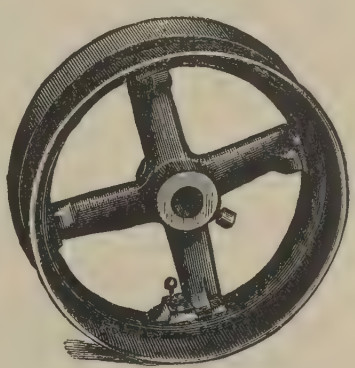


FIG. 176.—CARRYING PULLEYS FOR DUPLICATE CABLES.



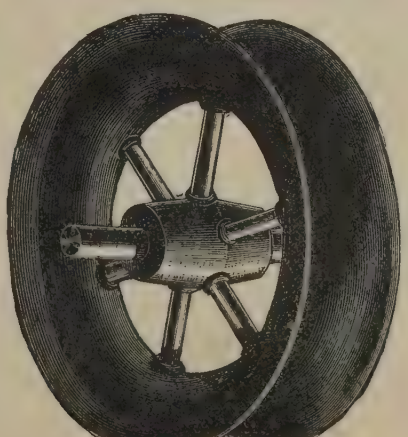


FIG. 177.—COMBINATION PULLEY.

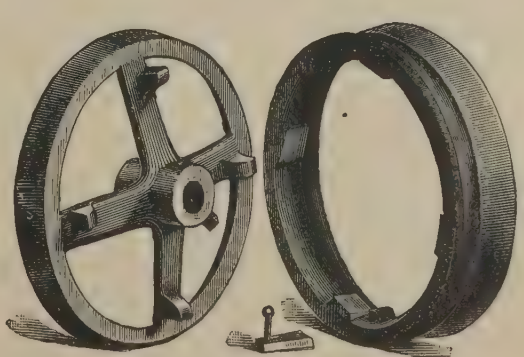


FIG. 178.—TWO PART ADJUSTABLE PULLEY.

fore they are put in service. It is the practice on some lines to line the groove of the carrying pulleys with babbit or other soft metal, the design being to protect the cable and to deaden the sound or hum of the cable and pulleys in the conduit. It is a question in the minds of engineers whether by lining the sheaves there is really any saving in operating expenses. It undoubtedly adds to the life of the cable, but this is offset by the expense of renewing the lining and the liability of the soft metal taking the lay of the rope, so that the matrix formed in the surface cuts the dressing out of the rope between the strands. By comparison of the wear of the groove and that of the cable the advantage is, in point of economy, in favor of the chilled groove.

The diameter of the carrying pulley has little to do with the power necessary to drive the rope. The best practice favors twelve inches. The diameter of the bearing, however, is an important consideration and should be made as small as possible, consistent with safety. Care should be taken that the pulley be made perfectly round, otherwise a disagreeable pounding will occur. The noise of the running cable which, in some instances, is so annoying to the residents along the line, may be greatly reduced by resting the pulley frames on some fibrous material or by mounting the spindles upon *lignum vitæ* bearings.

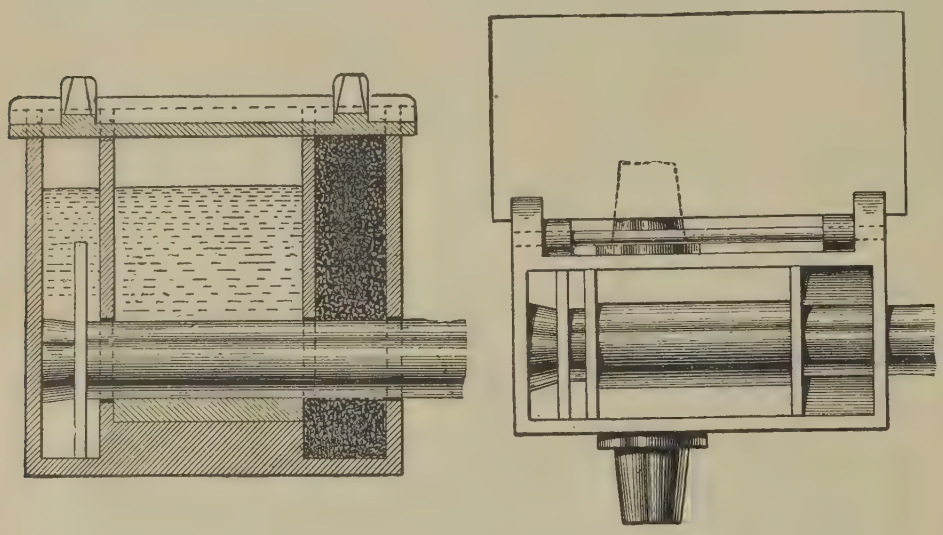


FIG. 181.—JOURNAL BOX FOR CARRYING PULLEYS.

Carrying pulleys should be mounted in a suitable journal box having ample oiling facilities. A pattern of box that is extensively used is illustrated in Fig. 181. It is hung on trunnions and has an end chamber, which, being packed with waste, prevents the escape of oil at the spindle. With this box a pulley will run several months without attention.

The curve construction for a cable road has taxed the ingenuity of engineers more than any other part of the work, and here again we find a great diversity of practice. A special pattern of yoke is required for curve construction, and the pulleys are, usually, placed near together in a horizontal position as in Fig. 182 the side pressure of the cable, between 600 and 800 lbs. on each pulley, being sufficient to hold it firmly against the pulleys. A guard rail is, usually, placed just above the curve pulleys which, following the contour of the slot, provides a rest for the grip on which it slides in passing, and holds the cable out from the pulley. (Figs. 183 and 184.) In some cases the slot rail is so arranged as to perform the functions of a guard rail also. (Figs. 185 and 160.) The curve pulleys are, usually, made with a wide face and bottom flange upon which the cable rides. Fig. 186 illustrates box and bearing for curve pulleys having a set screw for adjusting the pulley

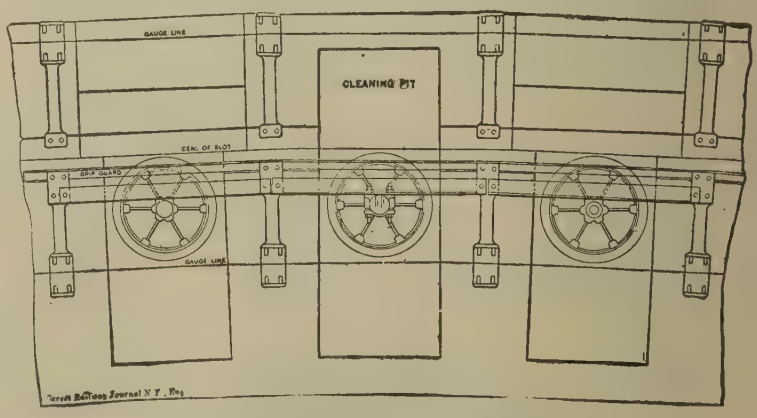


FIG. 182.—POSITION OF CURVE PULLEYS.

nd taking up the wear from the end of the shaft. A beveled babbit bearing supports the shaft. In ome cases the curve pulleys are made without a ange and a long carrying pulley is placed between

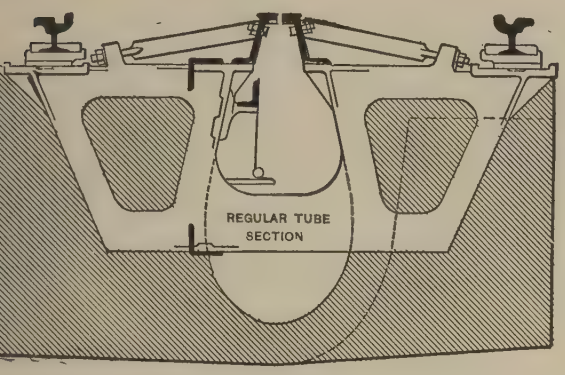


FIG. 183.—CURVE PULLEY AND GUARD RAIL.

188, are sometimes employed on curves in place of vertical faced pulleys.

The diameter of curve pulleys varies from fifteen inches to four feet, depending somewhat upon

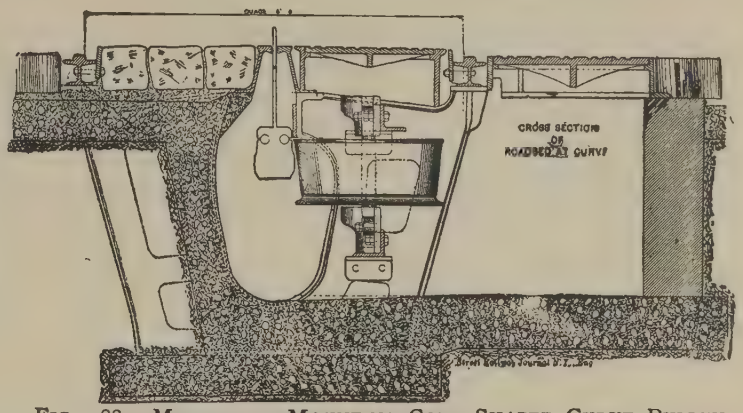


FIG. 188.—METHOD OF MOUNTING CONE SHAPED CURVE PULLEY.

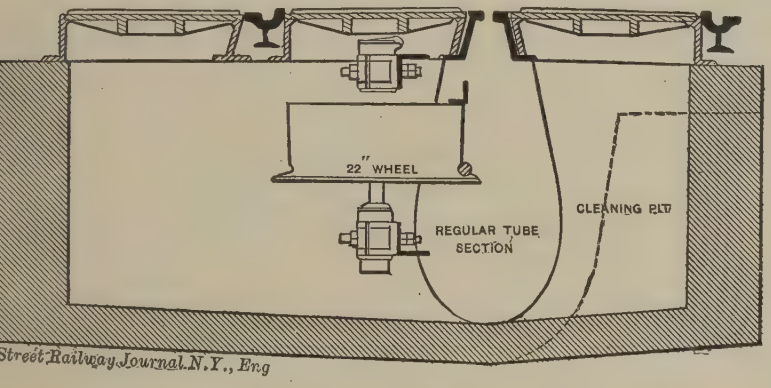


FIG. 184.—CURVE PULLEY.

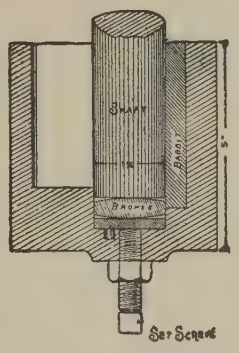


FIG. 186.—BEARING FOR CURVE PULLEY SPINDLE.

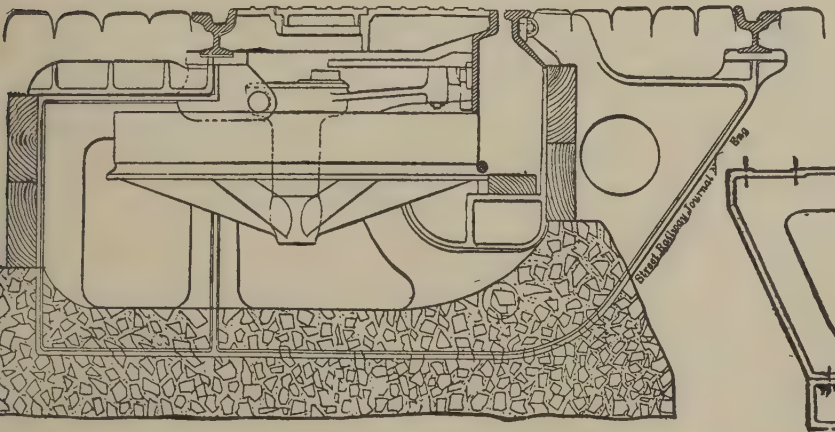


FIG. 185.—CURVE PULLEY MOUNTED FROM THE TOP—PROVIDENCE, R. I., LINE.

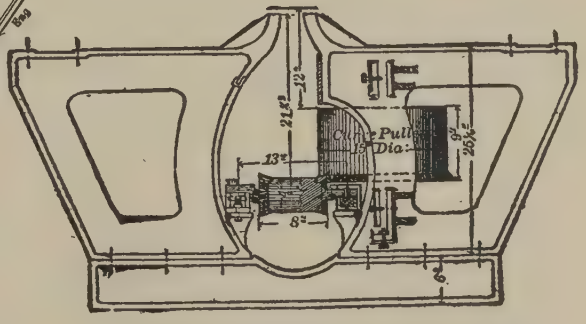


FIG. 187.—CURVE AND CARRYING PULLEY COMBINED.

wo curve pulleys to support the cable and prevent ts being chafed and worn by the flange, Fig. 187. Where the horizontal pulleys are placed close together the intermediate carrying pulley is not required. Vertical cone pulleys, illustrated in Fig. the radius of the curve. Practice has established the fact that it requires less power to operate a cable around an ordinary curve upon large pulleys than on small ones, and that with the large pulleys the cable has a much longer life. The power

required to drive a curve pulley is in about the same proportion as its peripheral diameter is to the diameter of the spindle. A large pulley also lasts much longer than a small pulley. In either case the pulleys should be placed as close together as possible, except on curves of very long radius.

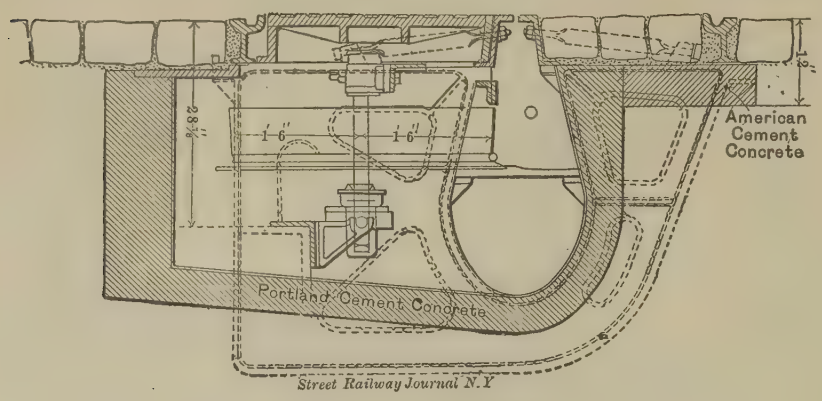


FIG. 189.—CURVE CONSTRUCTION—BALTIMORE PASSENGER RAILWAY.

The power required to operate a cable on a curve is not by any means all absorbed by the mere turning of the pulleys upon their bearings, but it is largely required for bending the cable an indefinite number of times as it passes the pulleys. If the curve pulleys are of the proper size and placed near together, the cable is not injured as much as it is likely to be over small pulleys placed too far apart. Fig. 185 shows a novel method of mounting a curve pulley. In this system the pulleys are nearly four feet in diameter, extending under the rail, but so mounted in a suspended trunnion bearing that, by releasing the cam lever which anchors them to the slot rail, they can be tilted up and removed through the opening between the slot and track rail. It will be noted in the same figure that the bottom of the conduit is lined with wood coming close up to the flange of the sheave. This is designed to prevent the cable from ever being drawn under the sheave in case it should become slack and drop below the flange. The cover is also provided with a hand hole through which the oil box at the top of the bearing may be filled. In Figs. 189, 190, 190A are shown approved forms of curve construction, which are self explanatory. Fig. 191 illustrates a form of curve pulley designed for use on the duplicate system. It really consists of three wheels on the same shaft. The upper one is thirty-two and the lower one forty inches in diameter. The top wheel has a flat face, against which the grip takes bearing in passing. The inner cable runs against the single groove sheave between the top, flat faced wheel and the lower wheel. The latter is conical in form, and has a spiral groove for guiding the outer and lower rope (when in use) down to its proper line after the grip has passed.

Curve pulleys may be cast in sections the same as carrying pulleys, and so arranged that the portion worn by the cable can be renewed without renewing the entire pulley.

Curves are the bane of cable construction. Their first cost is enormous; they consume power, materially shorten the life of the rope, and are a source of endless care and anxiety to the management. So many difficulties attend the operation of cables around curves that several roads have abandoned the pulley construction, where the grades are suitable, and turn the rope by means of one large sheave. In this case the grip is released, and the car is floated over the curve by momentum or gravity, when

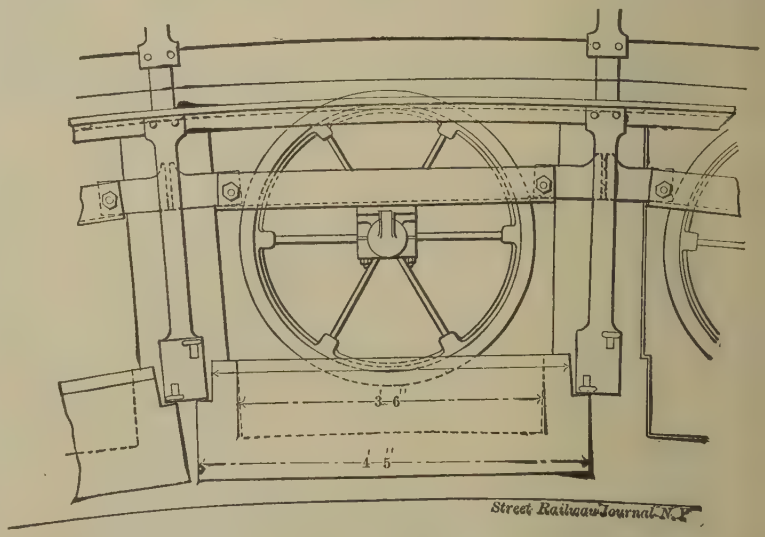
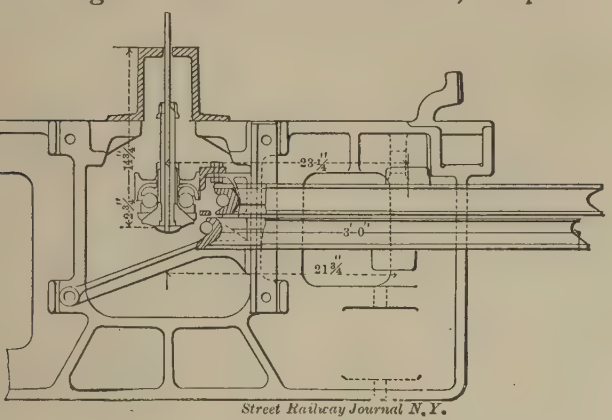


FIG. 190.—POSITION OF CURVE PULLEY—BALTIMORE PASSENGER RAILWAY.

he rope is again picked up. In our opinion a liding contact could be provided for the rope n curves in place of the usual pulley construction. This might consist of an endless belt, composed of



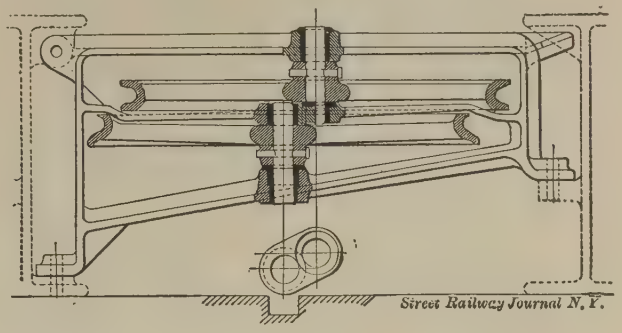


FIG. 190A.—PROPOSED ARRANGEMENT OF CURVE PULLEYS FOR DUPLICATE ROPES.

wooden blocks, each about a foot long, slightly rounded at the ends, bored out lengthwise, and strung like beads on a small wire rope or chain, which, being mounted in a concave curved bearing facing the conduit, would provide a suitable rest for the rope, and being properly lubricated would easily slide around the curve, completing the circle through a blind conduit or tube, under the pavement. With this device the rope would bend easily to the arc of the curve, and less power would be consumed.

In this connection we illustrate a set of elevating sheaves, Fig. 192, which also have been designed for use with duplicate cables. These are placed at the point where the rope passes into the conduit from the power house, or near the end of the line, and are used to elevate the ropes to a line where they may be received by the grip. Ordinarily, elevating sheaves are set in a line with the slot, and the grip is guided around them by short reverse curves made in the slot and track rails. To obviate the necessity of these curves, the tilting sheaves were designed. These are placed in a frame having trunnions at the ends on which the wheel tilts, and are in a line with the travel of the grip, but, by means of a long horizontal lever operated by the grip as it approaches, they are tilted to one side, and, as they assume their former position, the rope is placed between the grip jaws. Depression pulleys, as illustrated in Figs. 193 and 194, are used to keep the rope down in its place where there is a sudden change of grade upon a line, as when crossing a level street on a steep grade, or at the foot of a narrow valley. These are usually small sheaves arranged near together on each side and underneath the slot. Against these pulleys the rope rides when the strain overcomes the sag due to its own weight, and they prevent it from being chafed and worn by bearing against the under side of the slot rail. The grip

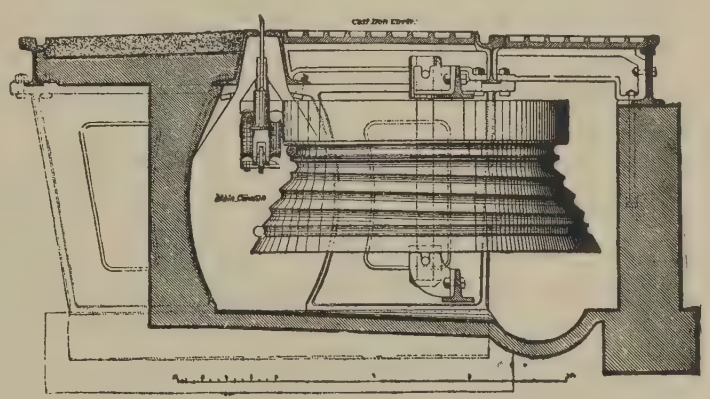


FIG. 191.—SPIRAL GROOVE CURVE PULLEY—TENTH AVENUE, NEW YORK, LINE.

in passing depresses the rope enough to clear the pulleys. There are other devices for this purpose in which the pulleys are carried by counter weighted levers, or upon vibrating frames which move to one side as the grip passes and return to their former position before the rope rises.

It is usually the practice in cable road construction to pave all or a portion of the surface between the slot and track rail on the inside of a curve with iron plates having corrugated surfaces. These

plates make a durable pavement, and they may be readily moved for inspecting the pulleys beneath.

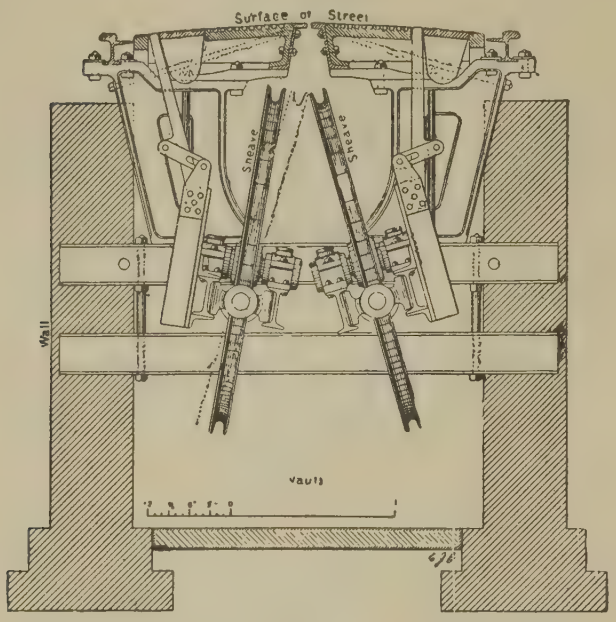


FIG. 192.—TILTING SHEAVES FOR PLACING ROPE IN GRIP.

(See Fig. 195.) Sometimes, however, oak planks are used for this purpose, and also for pulley vault covers, but are not very durable.

Roads have been constructed with a subway between the tracks deep enough for a person to enter, and from which curve pulleys can be renewed or adjusted. This is a convenient and not very costly arrangement. In this case the surface is paved in the ordinary manner.

Proper drainage is an important factor in cable construction. This may be provided for by connecting the conduit by drain pipes to the sewer at suitable intervals, or a line of sewer pipe may be laid along the street between the tracks, connecting a series of pulley vaults, which in turn may empty into the sewer or other channel. (See Figs. 160, 161, 162.) In case the line is built upon streets having no system of sewers, it is necessary to lead drain pipes into cesspools from which the water must be removed by pumping. See Figs. 171 and 173. Great care should be exercised to prevent an accumulation of water, or sand in the pulley vaults, for if the sand should block the pulleys, or if they should be stopped by the freezing of the water, the cable would soon cut them out or produce flat spots that would render them unfit for further service. It is not usually found necessary to trap the sewer connections of a cable conduit. In some large cities, however, it is required.

The cars may be transferred from one track to the other at the terminals of a cable road by a switch, a turntable or by means of a loop. In case a switch or turntable is provided, the cable passes around a large horizontal sheave mounted in a pit near the end of the line, as shown in Figs. 196, 197 and 197A. On the incoming line the cable is deflected to one side of the slot which releases it from the grip, and an opening or grip hatch is provided through which the grip may be lifted from the conduit. (See Fig. 174.) These hatches are also provided at intervals along the line, having hinged covers, so that a grip may be removed in case it should become disabled *en route*, or it becomes necessary to switch from one track to the other. When a turntable is employed it is usually operated by means of friction gear and clutches connected with the terminal

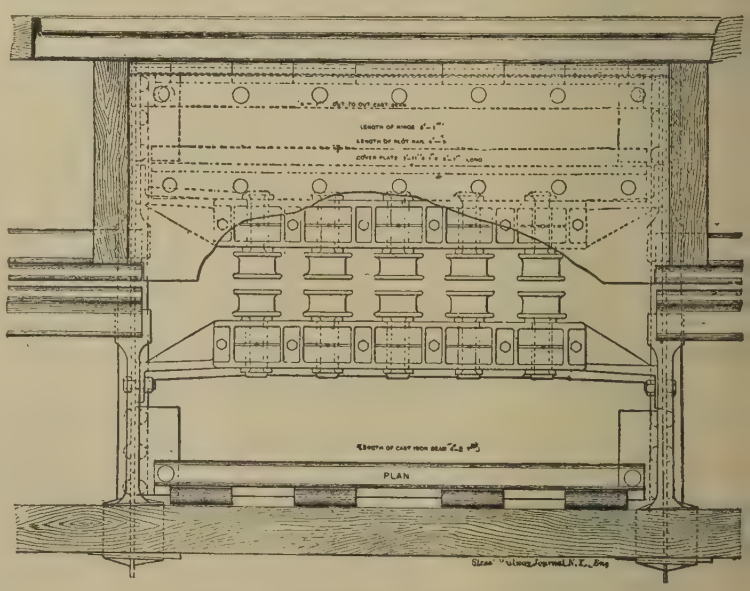


FIG. 193.—DEPRESSING PULLEY.

sheave. The loop construction may be laid in the street, or the line may be led around a block. In either case the ordinary curve construction is em

oyed, as shown in Fig. 198, which is known as e balloon loop. It will be noted, by reference to is figure, that the second pulley at the beginning each curve is omitted; this is done in order that e cable may exert sufficient side pressure on the

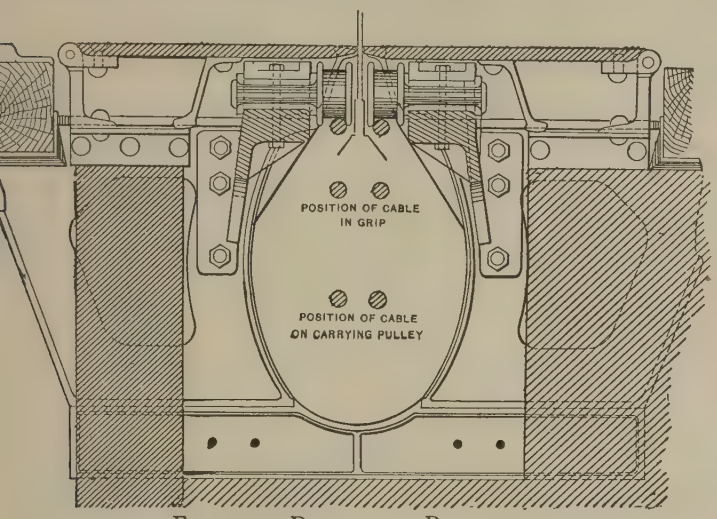


Fig. 194.—Depressing Pulleys.

rst pulley to cause it to turn. Ordinarily the de pull of the cable on the first pulley of a curve only half as much as on each of the others here they are equally spaced.

The choice between a switch, turntable or loop at ie terminals of a cable line is determined, usually, y the amount of traffic, the width of the street, nd the type of grip car in use. On lines operated ith the ordinary open grip car or ummy, and on some lines with a ouble grip on an ordinary car, that an run either end forward, the ordiary cable switch is employed. This so arranged that not only the rail ut the grip slot as well is provided ith a movable switch point or tongue r diverting the car from one track the other (Fig. 197B.) If possible, ie switch should be constructed on a slight rade, so that the car can be transferred by gravity, ius saving the expense of a horse for the purpose. he crossover may be arranged for either the coming or outgoing car. In the former case the able is dropped on approaching the switch, and ie grip car, being uncoupled from the trailer, asses over and couples on to another trailer already in waiting on the end of the return track, the grip car being in position to pick up the cable and start on the return. In the second case the cable is held till the crossover is passed and the trail car is uncoupled and passes the crossover, first coming in behind a grip car already in waiting and in position to pick up the cable. The last grip car in then drops over and remains in waiting for the trail car of the next train. These switch combinations for a dummy and trailer may be varied to suit the grades and conditions of traffic. In case the trailer is a horse car which must continue over a connecting line, the grip car only makes the switch, and remains in waiting for the arrival of its return tow or trailer. A very good construction for a flying switch for a grip car only is made with the rails of the crossover elevated two or three inches above the track rails, and the wheels of the grip car being provided on their inner faces with a second tread of less diameter than the rail tread, take this elevated rail and transfer the car without the intervention of tongues or frogs.

Trains or long cars may be transferred by means of a turntable, provided it is made large enough. There are some in use thirty feet in diameter. The tracks on the table must be provided with slot and tube way for the grip, forming a continuation of the conduit on the incoming and outgoing tracks. On approaching the table the rope is dropped and the car is run upon it by momentum, and after being turned it may be hauled to position on the outgoing track by means of a rope wound upon a windlass placed under the surface of the street and

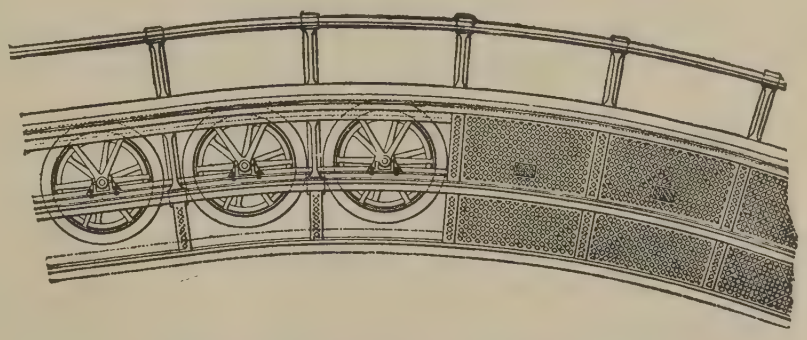


Fig. 195.—Curve Paved with Iron Plates—125th Street, New York.

driven with power derived from the cable by means of friction gear which is set in motion by a hand lever. Another hand lever serves to set the table in motion by means of friction gear, as before noted.

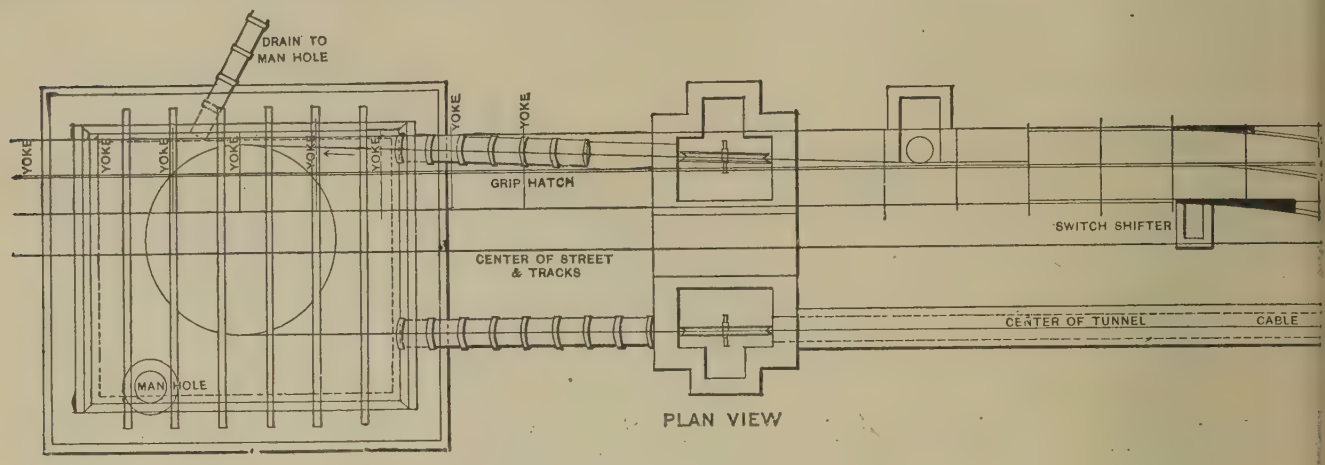


FIG. 196.—TERMINAL SHEAVE AND PIT.

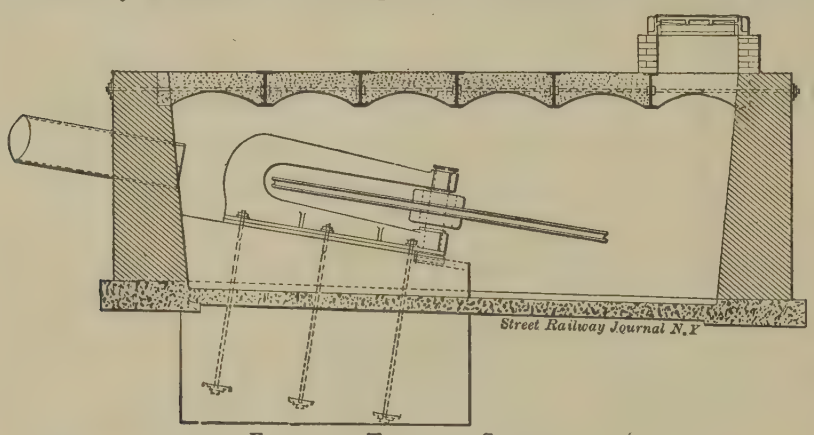


FIG. 197.—TERMINAL SHEAVE.

In order to provide for the dispatch of cars in rapid succession the turntable may be provided with two sets of tracks so disposed that when one car is turned and headed for its return track the other set of tracks on the table is in position to receive another incoming car from the main track. Two or more outgoing tracks or special sideways may also be provided, which converge into the main line at a suitable distance and thus facilitate the dispatch of cars. This is a valuable feature, especially where the cars of various lines have a common terminal. In some cases both switches and hand turntables are provided at the terminals. The ideal terminal, however, is the loop which provides for turning cars or trains of any length quickly, without special attendants. The loop may be operated at full speed by the main cable, or an auxiliary cable may be provided, which is operated at a slower speed by means of gears and drums driven from the main cable. When the loop is in the vicinity of the power house the auxiliary cable may be driven by special machinery in the power house and conducted to the curve through a blind conduit.

While the loop is the ideal method for turning cars it is expensive in first cost, absorbs power and is very hard on the rope. Other things being equal a cable line should be so designed that the rope will be required to do the least possible work. Curves, loops and auxiliary machinery should, if possible, be avoided.

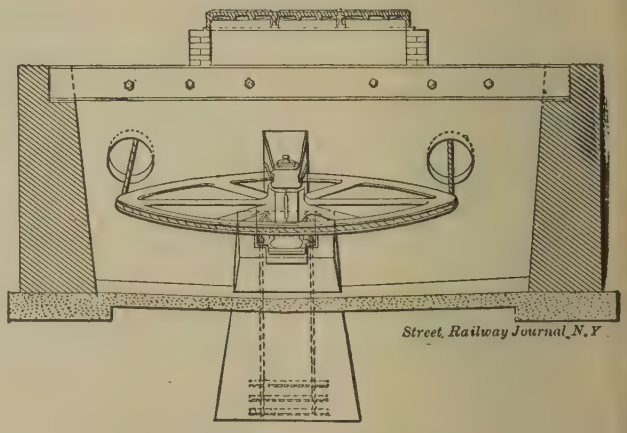


FIG. 197A.—TERMINAL SHEAVE.

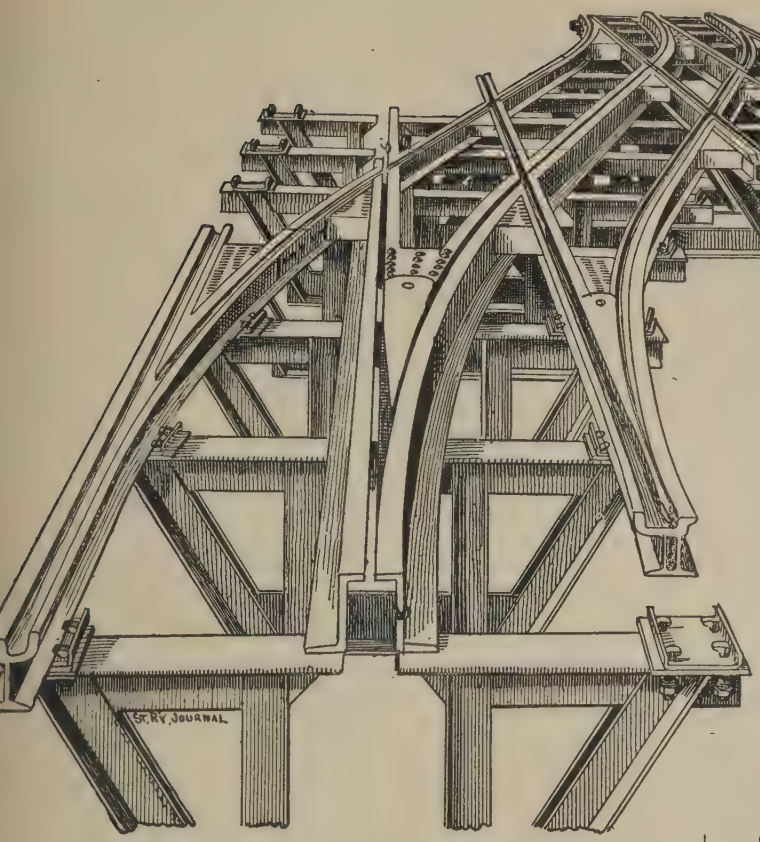


FIG. 197B.—CROSSOVER SWITCH—BROADWAY, NEW YORK, CABLE LINE.

Whenever a loop is employed it will be found f great advantage to operate some portion of it hrough a building on the company's property, vhere the tracks can be led over open pits, thus roviding facilities for inspecting and oiling the rip at each trip if necessary. These pits are usu-lly provided with steam pipes or stoves for varming, with electric or other lamps, and with uitable elevating sheaves for removing and re-lacing the cable in the grip.

Various devices are used for replacing the able in the grip after dropping it at the ter-ninals, when passing the power house or at cross-ngs. The device usually depends upon the pat-ern of grip in use. In some cases a slight bend n the track and slot rails, or in the slot rails nly, serves to swing the grip to one side, and he jaws being open the cable passes out, and is eturned in the same way. The same thing may e accomplished by means of a wheel and lever alled a "gipsy." This lever is, preferably, con-structed of inch and a half gas pipe supported by trunnion bearings between two yokes. The lever extends across the conduit and carries a conical roller six inches long, six inches in diameter at one end, and two and a half inches at the other. By means of a chain attached to the end of this lever and coming up through a hole in the surface of the street, the roller is lifted and, striking against the rope, not only raises it, but causes it to describe a half circle, drawing it out to one side, and when at a proper height it slides down to the small end of the roller and into the side of the grip. The chain may be operated by an attendant or by the conductor who leaves his car for this purpose.

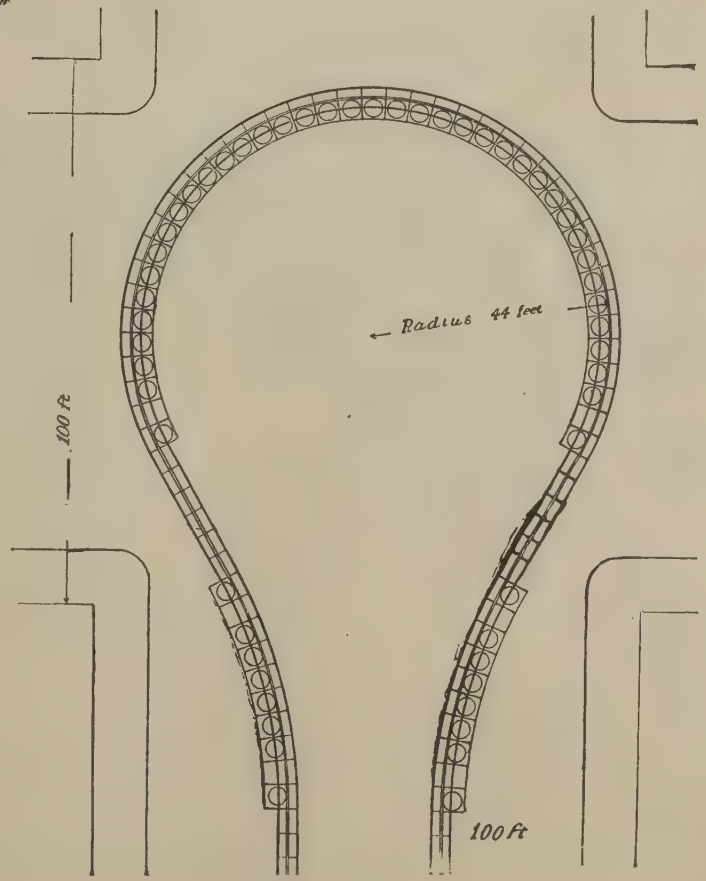


FIG. 198.—BALOON LOOP.

On some foreign lines an automatic rope lifting device is employed, which is illustrated in Figs. 199 and 200. A lever with which the grip shank comes in contact is hung just beneath the

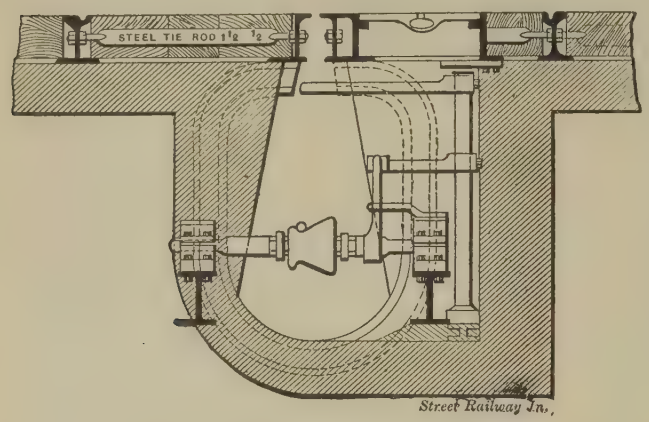


FIG. 199.—AUTOMATIC ROPE LIFTING GEAR.

slot and being swung around by the passing grip, lifts the rope into place.

With some patterns of bottom grips the cable is picked up by depressing the grip; others are provided with special hooks for this purpose, while another picks up the cable, as the car passes a slight vertical dip in the tracks.

In connection with the ordinary tube switch for branching lines, automatic safety appliances are sometimes provided which reset the switch and prevent the car from starting around the curve while the cable holds the grip to the straight line in cases where the gripman fails to drop the cable in time. This device usually consists of a long shaft, having a roller at one end and connected with the switch lever by bell cranks. This shaft being mounted to one side of the conduit, is revolved when the switch lever is moved, and the roller is brought on top of the rope in position to be lifted in case the grip fails to let go of the rope. In case it is lifted the switch is closed and the car keeps on the main line. It can then be stopped, backed up and moved around the curve without injury to the rope or grip.

In place of safety appliances, some lines station a watchman at all points where the cable is dropped, whose duty it is to watch the cable through an opening in the pavement, and to notify the gripman in time to prevent accidents in case the grip fails to let go of the rope. At all points where the cable is to be dropped and picked up a sign of some kind should be placed to notify the grip driver where to manipulate the grip or brakes. A durable sign for this purpose may be made of sheet iron and should be properly lettered with the words "Let go;" "Take up;" "Stop." At night the signs should be provided with signal lanterns. As there are always new men being employed, safety devices of this kind should never be discarded.

Where lines are operated in snow regions it is found to be of advantage to place a line of two-inch steam pipes in the bottom of the conduit, with valves and connections at suitable intervals, through which live steam can be admitted from a portable boiler, for the purpose of melting any accumulation of snow that may drift through the slot, and which would interfere with the free movement of the cable or pulleys

One of the difficult problems to solve in cable construction is to provide suitable support for the

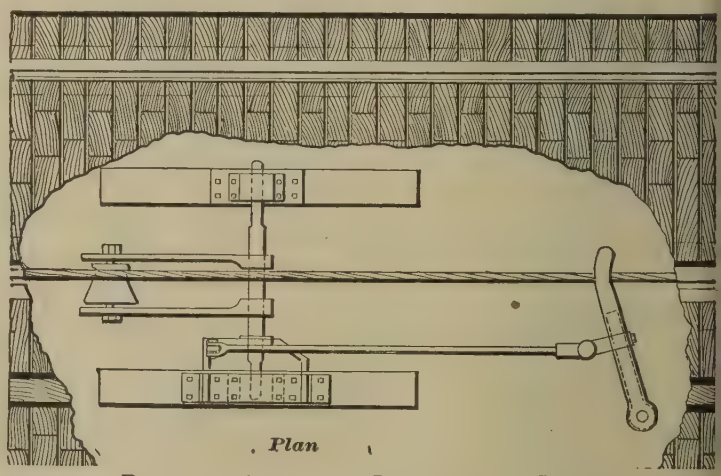


FIG. 200.—AUTOMATIC ROPE LIFTING GEAR.

rails at crossings, especially where the line to be crossed is a steam road, and to make at such crossings a comparatively smooth track for the cars. Most steam roads will not allow their rails to be notched for the flange, and if the track and slot rails are placed higher than the steam rails they

are liable to be broken by the wide tread of the locomotive drivers. In case the rail of the steam line cannot be notched for the passage of the flange of the cable car, wedge shaped pieces are sometimes riveted to the tram rail as shown in Fig. 201, upon which the flange rides at crossings. Special yokes, castings and angle plates are required for crossings, differing in form in nearly every instance. Fig. 201A illustrates a three track diagonal crossing for a street car line.

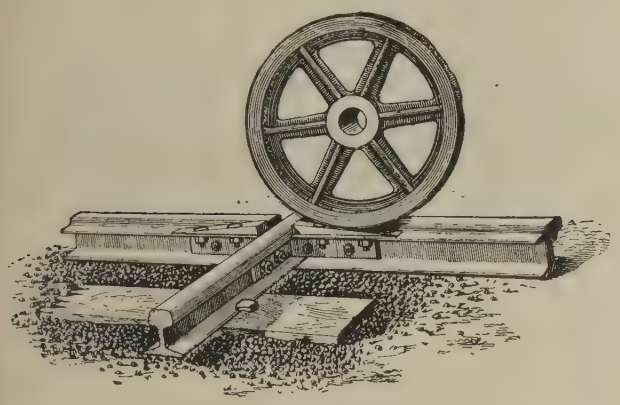


FIG. 201.—STEAM CROSSING.

Granite blocks, brick or asphaltum are the best materials for paving cable lines. Wood is not suitable on account of its liability to swell or expand in wet weather, producing sufficient pressure to close the slot. It may be used, however, between the tracks, as illustrated in Fig. 143. In case granite blocks are used on lines operated in cold regions the interstices should always be filled with cement, tar or other waterproof material, to prevent the water from percolating into the soil beneath, where it would be liable to freeze and close the slot. One objection to this method of paving is the difficulty of removing the blocks for the necessary repairs. The same objection may be urged against asphaltum, but where a road is so constructed that the slot rails do not need to be adjusted, nor the track joints raised, this material makes a very desirable pavement, for it is not affected by temperature, is waterproof, has an even surface, allowing the car fender to run low, and possesses many other advantages.

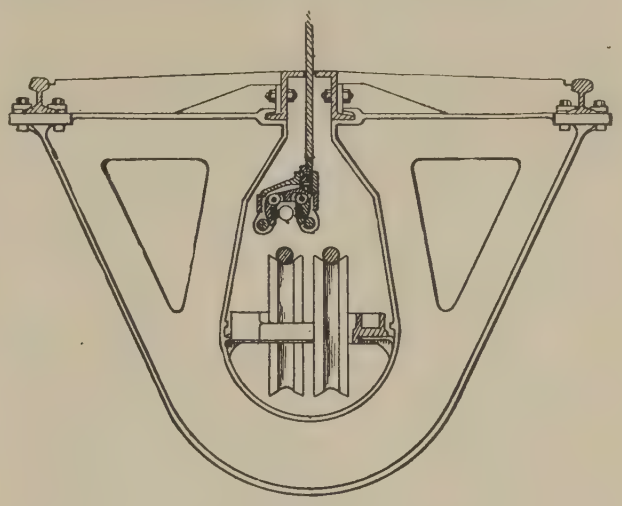


FIG. 202.—SINGLE TRACK CABLE CONSTRUCTION.

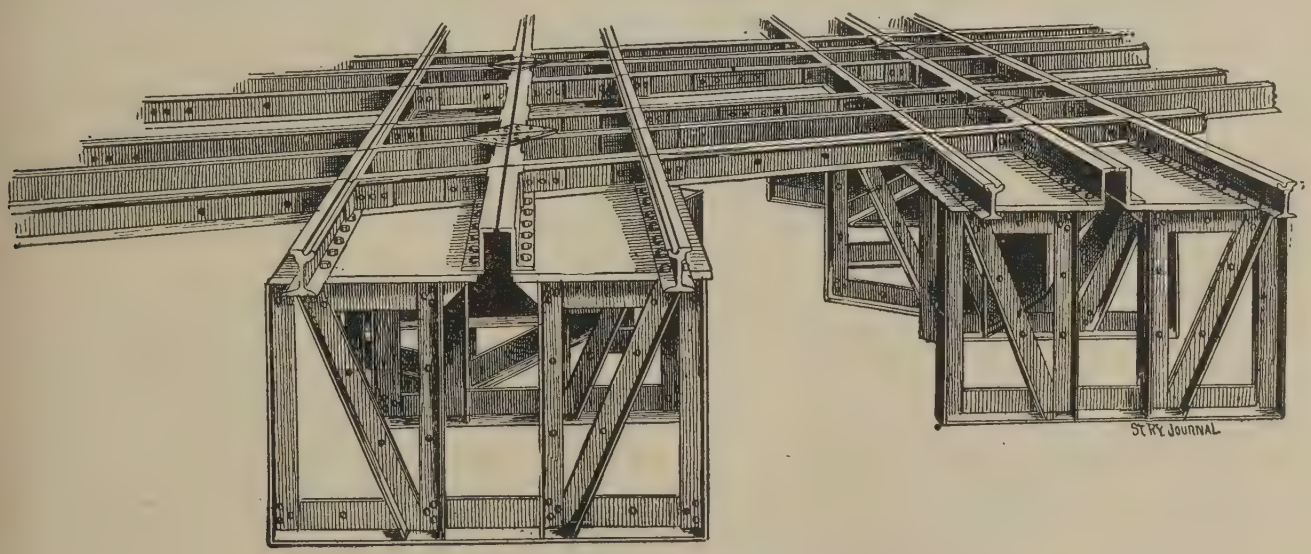


FIG. 201A.—CABLE CROSSING FOR A STREET CAR LINE.

The different types of track rail in use on cable lines are shown in connection with the yokes. The

best practice inclines to a heavy girder having great vertical stiffness In some cases local regulations require the adoption of a grooved girder rail. This type of rail, doubtless, interferes as little as any with wagon traffic, but it requires more power to operate the cars upon such a track than with other types. The joints should be supported upon the yoke, the rail being cold sawed when necessary to bring the joints in position. We are aware that many good engineers favor suspended joints ; practice has demonstrated, however, that supported joints are the most durable.

The above covers the essential points of the street construction for a cable line, although there are many other adjuncts which have been proposed, and on which patents have been granted, among these are methods for closing or covering the slot, none of which have come into extended use, however. A few single track lines have been built with turnouts on which the rope runs in both directions in the same conduit. The general construction of conduit, however, is about the same as for a double track line, as will be seen by reference to Fig. 202, which illustrates the yoke, slot rails and posi-

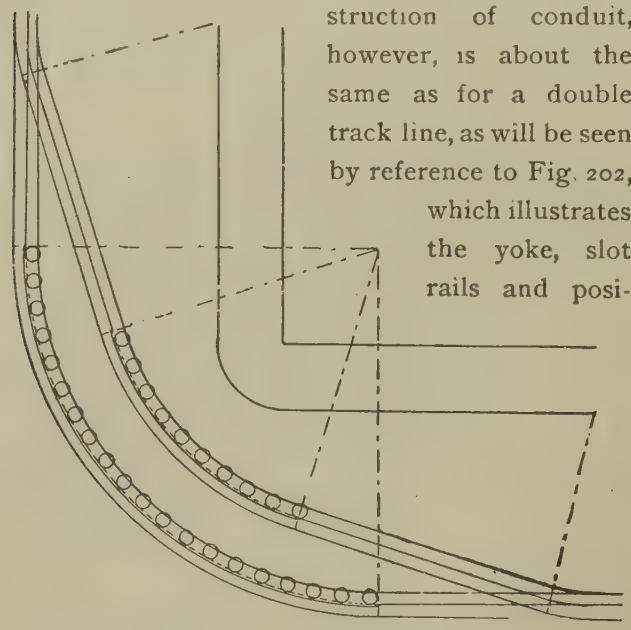


FIG. 203.—TURN OUT ON CURVE—SINGLE TRACK CONSTRUCTION.

tion of carrying pulleys of a single track line that operates very successfully. Both carrying pulleys are mounted in the same frame in position to prevent the two lines of rope from chafing together or against the sides of the conduit. Three forms of curve construction are admissible on single track lines. It being difficult to carry the two sections of rope which run in opposite directions around the same arc, double tracks may be employed which when properly located will serve as turnouts. (Fig.

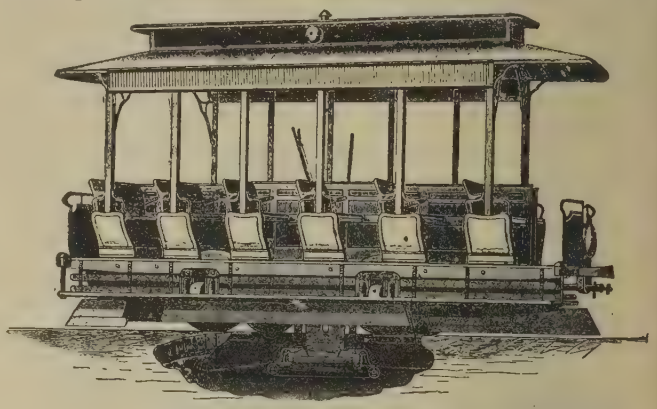


FIG. 204.—GRIP CAR, SHOWING CABLE IN GRIP WHEN DRAWING A TRAIN.

203) When this is not practicable and the curve must be made on a single track, one rope may be carried at a higher level than the other by placing the curve pulleys alternately for the high and low ropes. In this case it is necessary for the car that is hauled by the lower rope to release the rope and round the curve by momentum or gravity. The second rope is sometimes carried outside the main curve in a separate blind conduit, and the car in one direction drops the rope as above. Economy in cost of construction is the only advantage in the single track construction. It admits of the cable system being adopted in small cities and towns where the cost of a double track would be prohibitory.

THE GRIP.

This is the second important factor in cable traction, and may be described as a powerful vise, supported under a car within the conduit by means of a thin shank, and operated by a lever or wheel through the medium of an eccentric toggle joint or equivalent device, and made to grasp the rope with pressure sufficient to impart the motion of the rope to the car. It is shown in action under the car in Fig. 204.

Fig. 205 shows a grip in detail, and the following letters refer to corresponding parts.

A lever, B handle, C rod for raising dog, D dog, E dog spring, F quadrant, G adjustable head, G^1 adjustable shoe H

set screw, I adjustable screw, J links, K beam, L shank, M movable plate, N upper jaw, O lower jaw, P spools, Q roller journals, R rollers, S cable.

Fig. 206 is a modification of the same.

The type of grip used on the early cable roads differed materially from the one above described, but has never come into extensive use. The jaws of this first grip had a horizontal motion and were supplemented by four inclined pulleys arranged in pairs which assisted in grasping the cable. The grip was operated by means of a hand wheel fixed upon a screw spindle, which worked in connection with a sliding piece supported by the shank.

In the advance of cable practice the grip has undergone a great many modifications and hardly any two companies have adopted the same pattern.

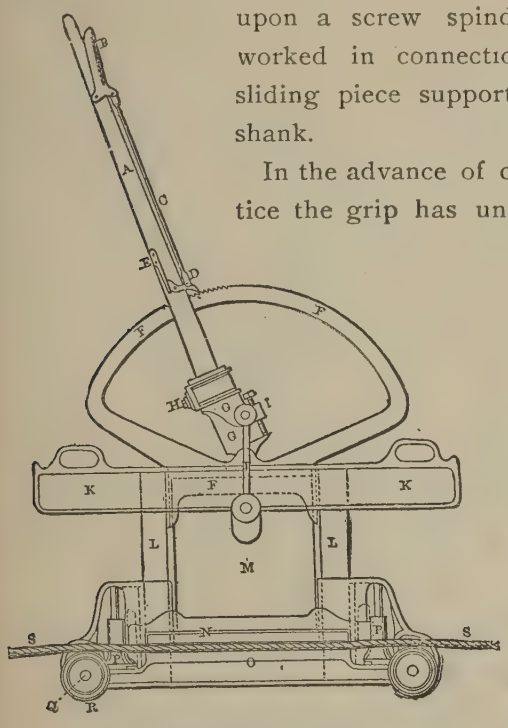


Fig. 205.—Cable Grip.

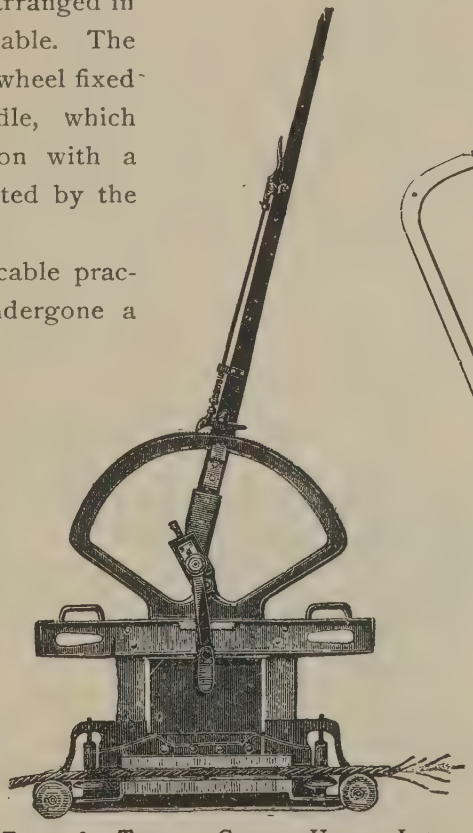


Fig. 206.—Type of Grip in Use on Lines of the Chicago City Railway.

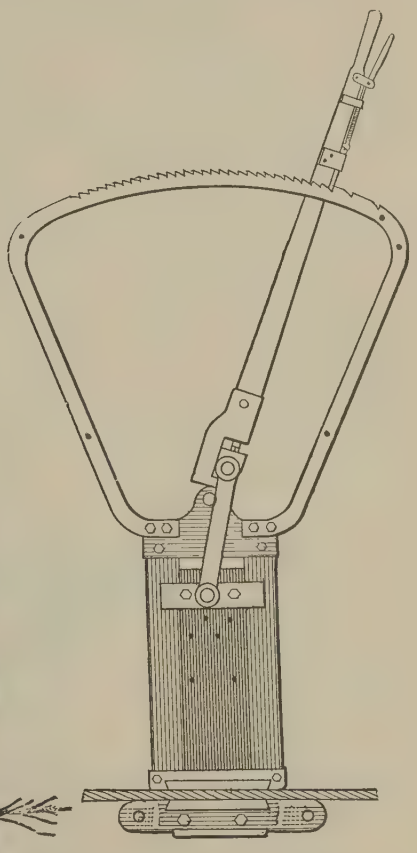


Fig. 207A.—Grip Employed in New Zealand.

For convenience of description they may be divided into two types, the vise and the roller grips: the former may be subdivided into the side grip, top grip and bottom grip. Each of these may be operated by means of levers directly over the grip, as above described, or by of means of levers or hand wheels through the medium of rods or chains from the car platforms.

The side grips usually have a pair of jaws on each side of the shank, and may take the rope on either side without the necessity of turning the car.

The grip jaws are usually from eighteen to twenty inches long and are lined with removable dies, to take the wear caused by the slipping of the rope when starting or running slower than the rope. The dies may be formed in short sections or the full length of the jaw, and should be of some durable metal. Phosphor bronze and other composition dies give good service, but those of cast steel or tool steel are found to have the longest life. In the choice of material, however, the life of the die should not always govern; the effect upon the cable must also be considered. The dies are usually formed with a slight groove to fit the rope and are sometimes made reversible.

In the grip above described the lower jaw is fixed and the upper one is movable. Other patterns have the upper jaw fixed, as illustrated in Fig. 207. It is claimed for this pattern that when the car is standing the rope is running nearer to its normal level, and the down pull

upon the grip is not so great and, consequently, there is less wear and loss of power. This lifting of the cable by the grip requires considerable power—more than is generally supposed.

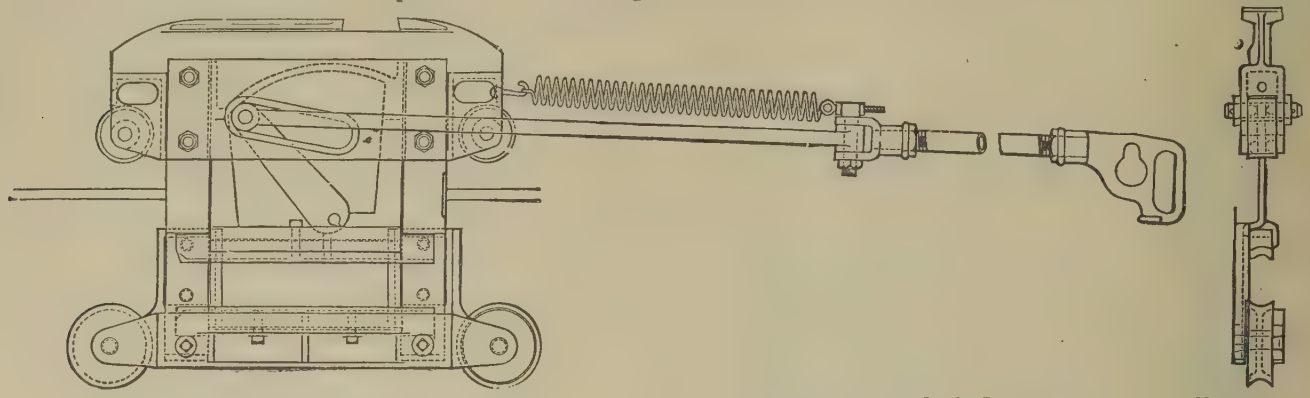


FIG. 208.—GRIP IN USE ON CINCINNATI STREET RAILWAY CO.'S LINE.

FIG. 208A.

By reference to Fig. 207 it will be noticed that the spools for throwing the rope out of the grip differ somewhat from those shown at P in Fig. 205. In this case the rope is removed by throwing the lever clear over, which serves to lift the conical spools and dislodge the rope, but in Fig. 207 the spools are moved sideways by a second lever and connections.

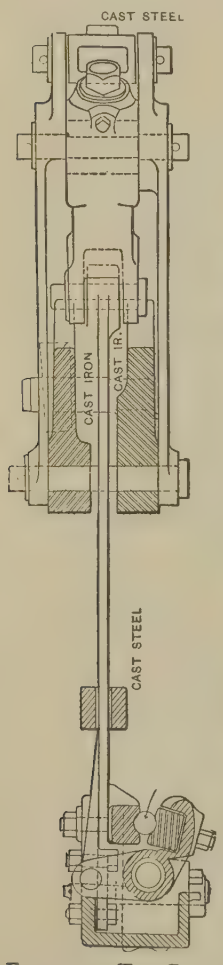


FIG. 209.—TOP GRIP.

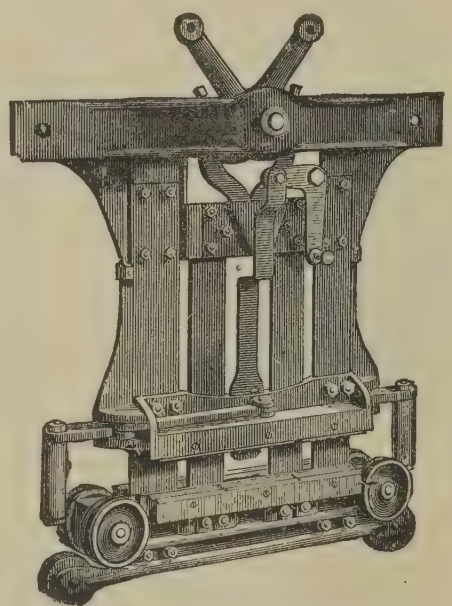


FIG. 207.—TYPE OF GRIP—TENTH AVENUE, NEW YORK, LINE.

Some do not regard the spools or the rollers as essential attachments to a grip. The rope may be removed from the grip by passing a short bend in the slot rails as before described, and it may be left to slide directly upon the lower die without injury. The difficulty of keeping the rollers properly lubricated and from becoming clogged by tar and dust, has caused them to be discarded on many lines.

The grip illustrated in Fig. 207 is operated by drawing the two short arms together by means of rods, actuated from the platforms by a hand wheel or lever, as before stated. Figs. 208 and 208A illustrate a side grip which is operated from the platform through a connecting rod, as shown. This pattern was specially designed for a detachable grip, in order to readily convert a horse car into a grip car, and the reverse. The top of this grip has a T shaped head, and is supported in a housing

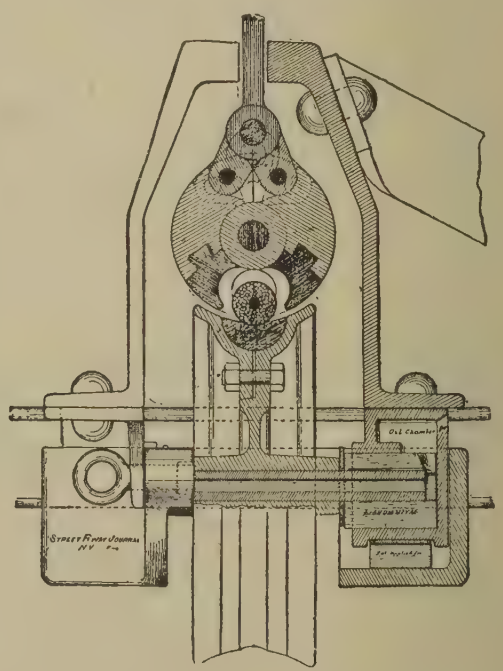


FIG. 210.—TYPE OF BOTTOM GRIP.

having a T shaped opening from end to end so that it may be easily slid out and dropped down to rest upon the slot, in which position the car passes over it. The housing rests upon a framework attached to the car axles, and is provided with all the devices for lateral motion, and the spring draught attachments common to other grips.

Fig. 209 is an end view of the top grip, in which, it will be observed, the outer jaw has a side motion, and closes in upon the rope which is received from the top, as indicated by the arrow. The rope is readily removed from this grip by being slightly elevated, whereupon the grip passes under and away from it. It will return to the jaws when running at its normal level. This grip is designed to be operated from the platform of either a four or eight wheel car.

Fig. 210 illustrates a type of bottom grip, which is designed to work in a very shallow conduit. It has the advantage of being able to drop or pick up the cable readily. The rope may be lifted and placed between the jaws of a bottom grip by a hook, or the grip may be depressed, or it may be made to pick up the rope at suitable points by having a dip in the track rails.

An upper jaw pattern of grip, and one operated by means of a screw spindle and hand wheel, is illustrated in Fig. 211. This grip is adapted for use on open grip cars which do not turn at the end of the line, as its workings and movements are the same with either end of the car forward. The screw rod is three-fourths of an inch in diameter, with four square threads to the inch, and it is turned by means of a twenty-inch hand wheel which, with seventy pounds exerted at the periphery, gives a maximum pressure of 17,590 lbs. on the rope.

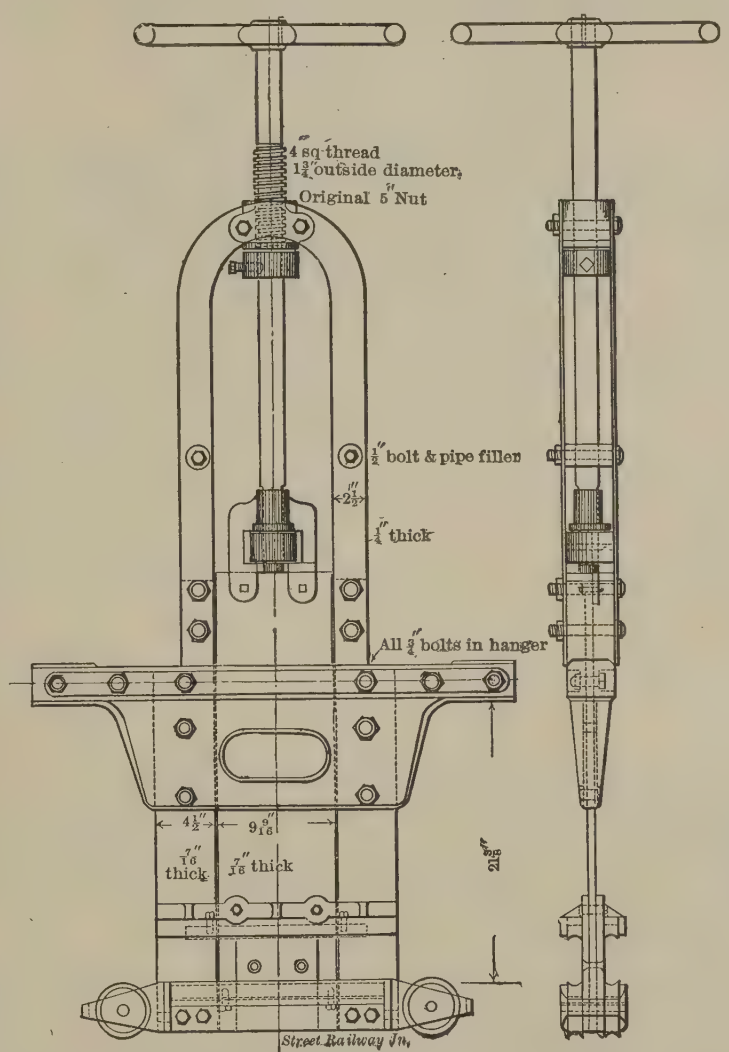


FIG. 211.—SCREW SPINDLE GRIP—PROVIDENCE, R. I., CABLE LINE.

Grips are usually supported by framework from the axles of the car, and not from the car body, and there are various methods of mounting the grip upon its frame, but it is usually so hung that it may have seven or eight inches of lateral motion to provide for its conforming to the short bends in the slot, which are made at the curve approaches, or at points where the rope is dropped or picked up. The draught attachment to the frame may be rigid, or consist of springs to prevent the car from starting with a sudden jerk. The springs are not necessary, however, provided the gripmen exercise proper care at starting.

Figs. 212 to 214 are views of a powerful roller grip, designed only for operating lines where the cable is above the surface, and is a modified form of the one long in use on the Brooklyn Bridge. It has two pairs of horizontal wheels, having grooves lined with rubber and leather, supplemented with short solid rubber lined jaws, the rope being lifted in place by external means. The pressure for holding it is transmitted to each wheel from the car plat-

form by means of a hand wheel and rods through the medium of a wooden brake shoe, applied to the inside surface of the rim, which is flanged for the purpose. The brake shoe serves the double purpose of applying the pressure and of checking the motion of the wheels until they cease to turn, when the car will travel at the same speed as the rope. This grip is admirably adapted for heavy traffic, and is usually attached to each car of a train. All the gripping faces being lined with soft material, this grip is very easy upon the rope.

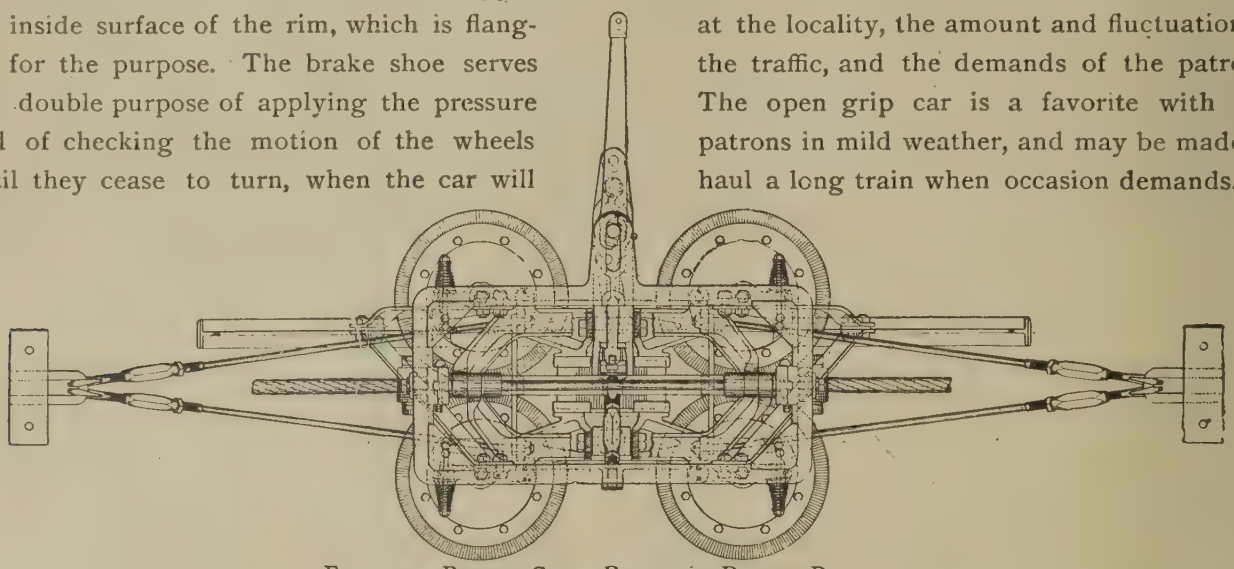


FIG. 212.—ROLLER GRIP—BROOKLYN BRIDGE RAILWAY.

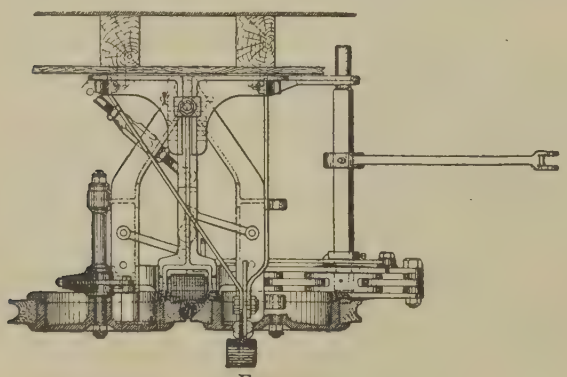


FIG. 213.

Fig. 215 represents the relation of car, grip, ropes and carrying sheaves of a duplicate system before mentioned, and Fig. 216 illustrates a combination eight wheeled car, which has the additional equipment of a track brake. The choice of operating a cable line with short open or dummy cars, capable of towing one or more cars, or with the grip mounted on an ordinary car, or upon a combination double truck car, depends somewhat upon climate at the locality, the amount and fluctuation of the traffic, and the demands of the patrons. The open grip car is a favorite with the patrons in mild weather, and may be made to haul a long train when occasion demands.

The use of an ordinary car with the grip driver always on the front platform, is regarded as the safest method of operation. The combination car, has advantages not to be overlooked, and has come into extended use. On lines where there are numerous short curves the double truck cars are in special favor, for they take the curves at high speed with a more agreeable motion than cars having a rigid truck.

THE CABLE.

This is the name given to a steel wire rope used for the transmission of power in the operation of street railways.

The majority of American roads employ a rope composed of six strands twisted around a heart of hemp rope (Fig. 217). Each strand is composed of nineteen wires, seven of them forming the heart

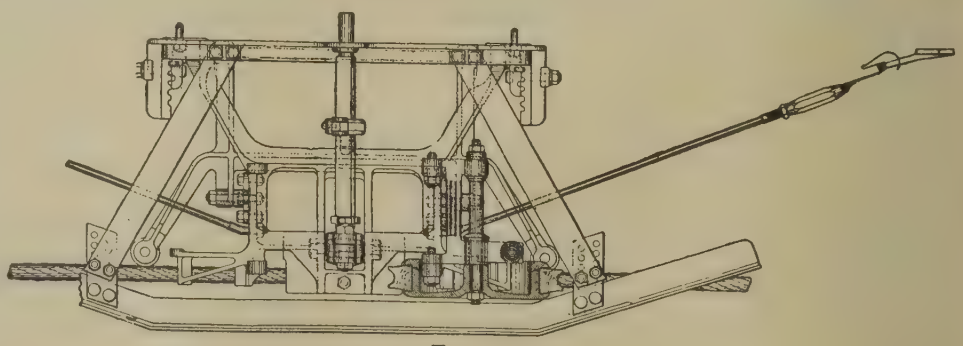


FIG. 214.

of the strand, around which the remaining twelve are wrapped. As these latter receive all the wear, they are sometimes made larger than the wires composing the core of the strand (Fig. 218), and the relative number of outside and inside wires may be varied. Ropes are also made with six strands of sixteen wires each, and others have seven strands composed of nineteen wires. In nineteen wire strands the wires are usually laid twelve over six over one. See Fig. 219. On straight lines the nineteen wire strand ropes give excellent service, but are not thought to be as serviceable on lines having curves.

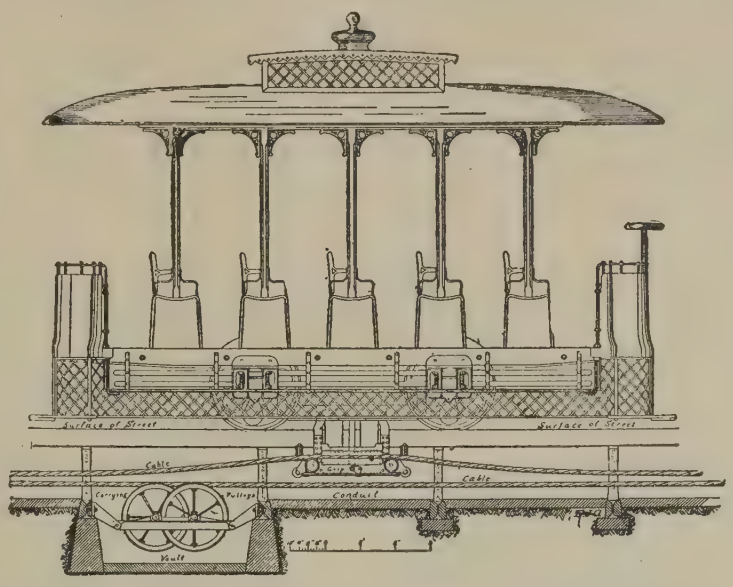


FIG. 215.—RELATION OF CAR GRIP AND CARRYING SHEAVES—DUPLICATE SYSTEM.

The size of a rope used in cable haulage varies, according to the work to be done, from one inch to one and a half inches in diameter, the usual diameter being an inch and an eighth and an inch and a quarter. The breaking strain of an inch and a quarter rope is about eighty tons, and such a rope weighs about two and half pounds per running foot. Ropes are also made with a wire centre, and while it is claimed that they are stronger, they are not as flexible, and hence not adapted to street railway work.

Foreign practice favors the employment of a different pattern of rope which, it is claimed, has a much longer life than ropes of ordinary make. This is known as the Lang lay, Albert lay, or long lay (Fig. 220), and its peculiar feature is that both the wires forming the strands and the strands themselves are laid in the same instead of opposite directions, subjecting a larger portion of each individual outside wire to wear and making an exceedingly flexible rope. The result is that the wires after long wear do not break at the crown of the strand (Fig. 221), as is the case with ropes made with

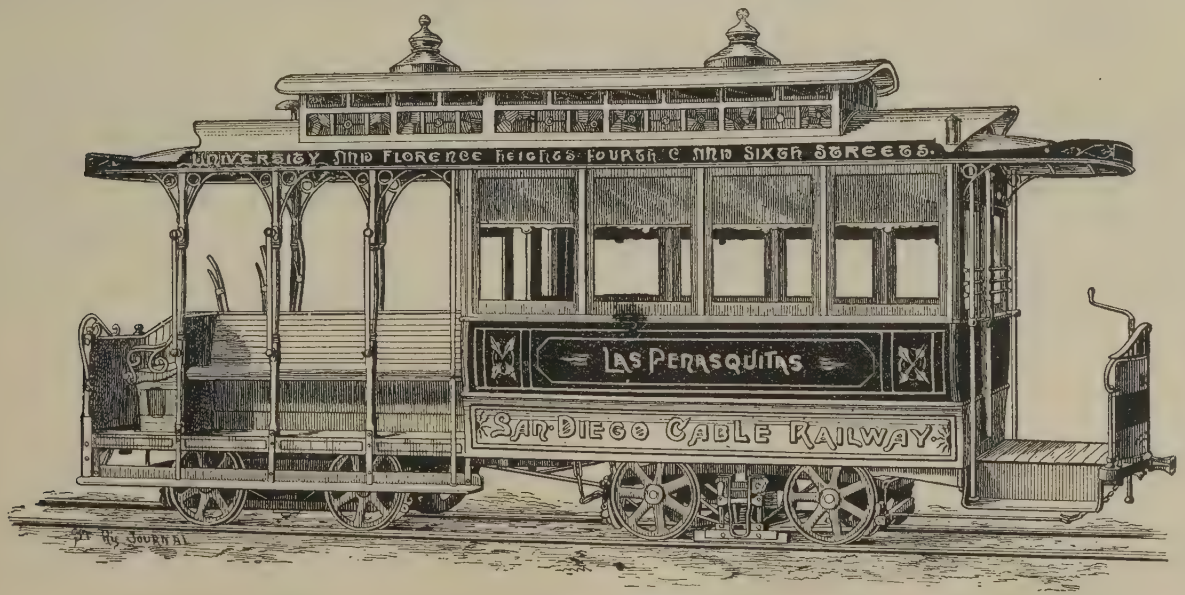


FIG. 216.—COMBINATION CAR—SAN DIEGO CABLE TRAMWAY.

wires and strands in opposite directions, as shown in Figs. 222 and 223. A striking contrast, showing the effect of service on the two types of rope, is illustrated in Fig. 224, in which the section lying diagonally across the coil is the Lang lay. This section was spliced into the other and made the same number of miles, but, apparently, is good for still further service.

This pattern of rope is manufactured by certain firms in this country, and can be made by all rope makers. Its general adoption would, no doubt, work a large saving in the expense account of cable railways.

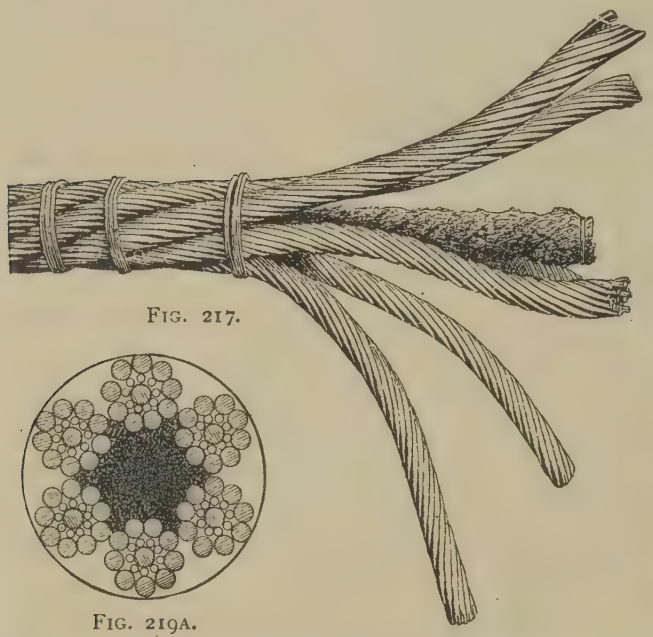


FIG. 217.

FIG. 219A.

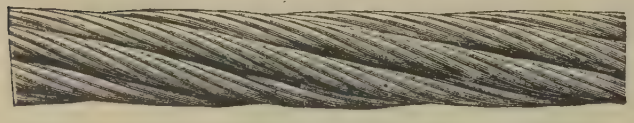


FIG. 220.

Fig. 225 is a section of ordinary rope having an excellent record. The cut shows its condition after being in service on a heavy line for 419 days, and having made 100,560 miles. The average life of ropes by the same makers that have been used on one of the most extensive lines in this country has been twelve and a half months, with an average of 88,402 miles.

Other types of ropes are made in which the strands are composed of special shaped wires (Figs. 226 and 227), but these have not come into extensive use.

The second of these is known as the California cable, and from Fig. 227A, which shows a section of a strand, it will be noted that a centre round wire is covered with six round wires, and these again with six round and six broad, triangular shaped wires, laid alternately, with the broad faced wires slightly overlapping and protecting the adjacent round wires, so that most of the wear comes on the triangular wires, on account of the larger surface exposed. The other is known as the locked wire rope, and is composed of steel wires throughout, there being no hemp centres. It is claimed to have less weight than ropes of other patterns of corresponding strength. It cannot be spliced in the ordinary manner, however, but the ends are joined by electric welding, which is done without enlarging the diameter or diminishing its strength at the point of welding. Experiments with the locked wire rope on cable lines have not been attended with encouraging results.

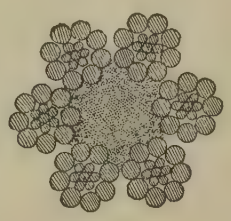


FIG. 218.

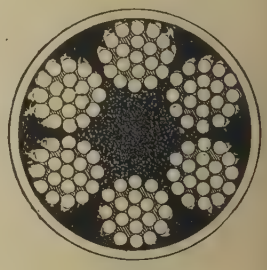


FIG. 219.

FIG. 222.—AFTER MAKING 71,241 MILES.

FIG. 223.—AFTER MAKING 65,575 MILES.

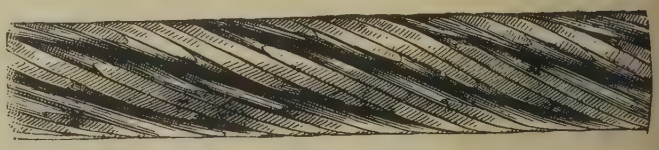


FIG. 221.—AFTER RUNNING 826 DAYS.

The life of the ordinary rope in service depends,

sually, upon the quality of the metal, the method f driving, the length and speed of the rope, num- er of curves and turns and amount of traffic. The general average in this country, including all ines and different makes of rope, is about eight nonths, while the mileage ranges from 40,000 to 50,000. The above conditions, however, do not lways govern, for it is the universal testimony hat while the rope makers, apparently, are doing

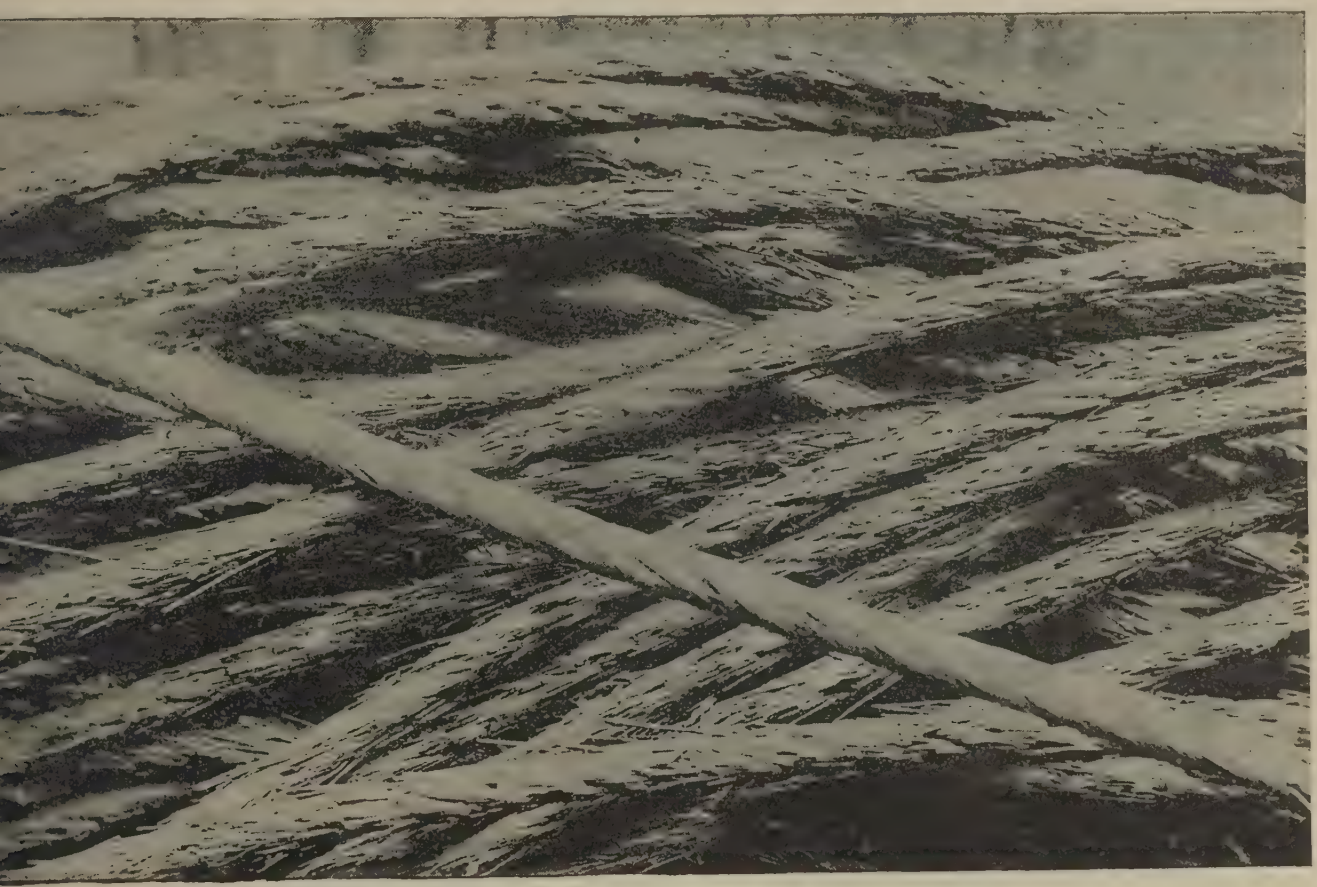


FIG. 224.

their very utmost to produce the best rope for this business, yet the ropes from the same makers do not give uniform results as to wear, one rope having a long life, and the next, of the same make, lasting only a brief time, under the same conditions. What seems to be required is some improvement in the metal from which the wires are drawn.

Ropes are frequently rendered unserviceable more from abuse than from use, which shows that they must have constant care and attention. A rope may be abused by allowing it to slip off a curve pulley and chafe against the yokes or concrete. A case in point is where a rope cut through the side post of a yoke by chafing against it, and imbedded itself into several other yokes. By far the greatest abuse, however, that a rope receives is from careless gripmen, who sometimes hold the rope too long on approaching a switch or other points where it is to be dropped, in which case the rope is cut or stranded.

Samples of rope that have been damaged by this means are shown in Figs. 228 and 229. In the first case one strand was cut, which was unwound about fifty feet before it was discovered, and in the second, two strands were cut, which ran out about 150 ft. In neither case did the gripman report his mishap, but left it to be discovered at the power house. On lines where loop terminals are provided, the danger of cutting the rope at these points is avoided.

For transportation a rope is usually wound on a

large spool in the same manner in which thread is wound. (Fig. 230.) This, being delivered in position, and mounted on a shaft with suitable bearings, slowly revolves, unwinding the cable as it is strung along the line of the conduit. The shaft on which the cable spool is mounted is usually made of hard wood, from twelve to sixteen inches square, with journals turned at the ends. These revolve in bearings thoroughly lubricated, and mounted on a solid timber foundation. In some cases a frame is provided with metal journal bearings, always kept in a suitable position, with a new rope mounted ready to be put in service. In place of the wooden shaft, a hollow cast iron shaft with journals is sometimes provided.

In case a portion of a cable line is near the station of a steam line or crosses a steam line, a good deal of trouble and expense may be saved in the handling of the rope, by having it shipped from the manufacturer, not on a spool, but coiled on the platform of one or more freight cars. It can then be uncoiled and introduced directly into the conduit, through a pulley vault opening. A rope being shipped on a spool, and no vehicle of sufficient strength being at hand to transport it to the power house, if may be safely and quickly trans-

FIG. 228.

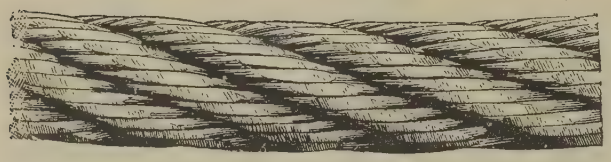


FIG. 225.—AFTER MAKING 100,560 MILES.

FIG 226.—LOCKED WIRE ROPE.

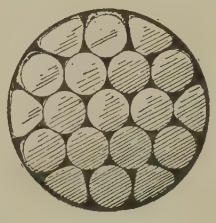


FIG. 227. CALIFORNIA ROPE. FIG. 227A.

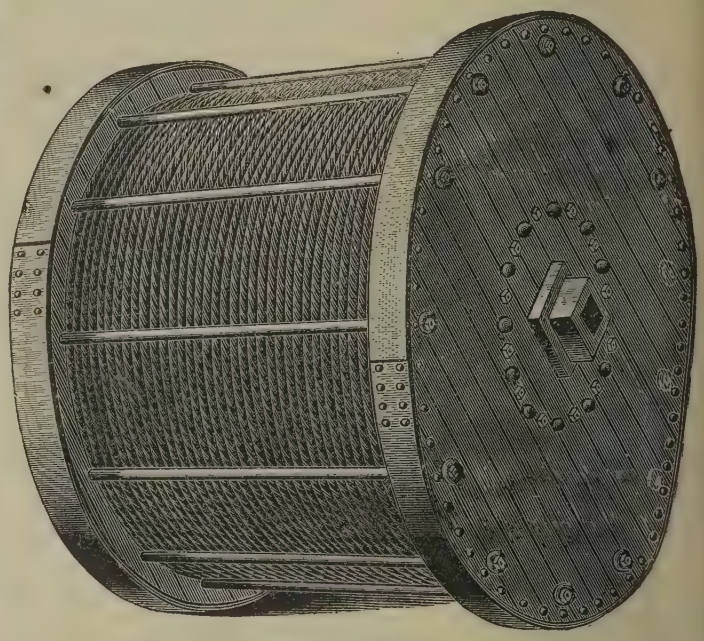


FIG. 230.—SHIPPING REEL.

FIG. 229.

ferred by rolling it on its own circumference by horse power, as shown in Fig. 231.

For shipment by water, a heavy rope is often transported by coiling it into large wooden tanks placed in the hold of a vessel, and it may be delivered to the vessel or removed by coiling it upon a train of wagons. Great care, however, must be exercised in handling a rope in this manner lest half kinks be introduced which often develop as destructive factors.

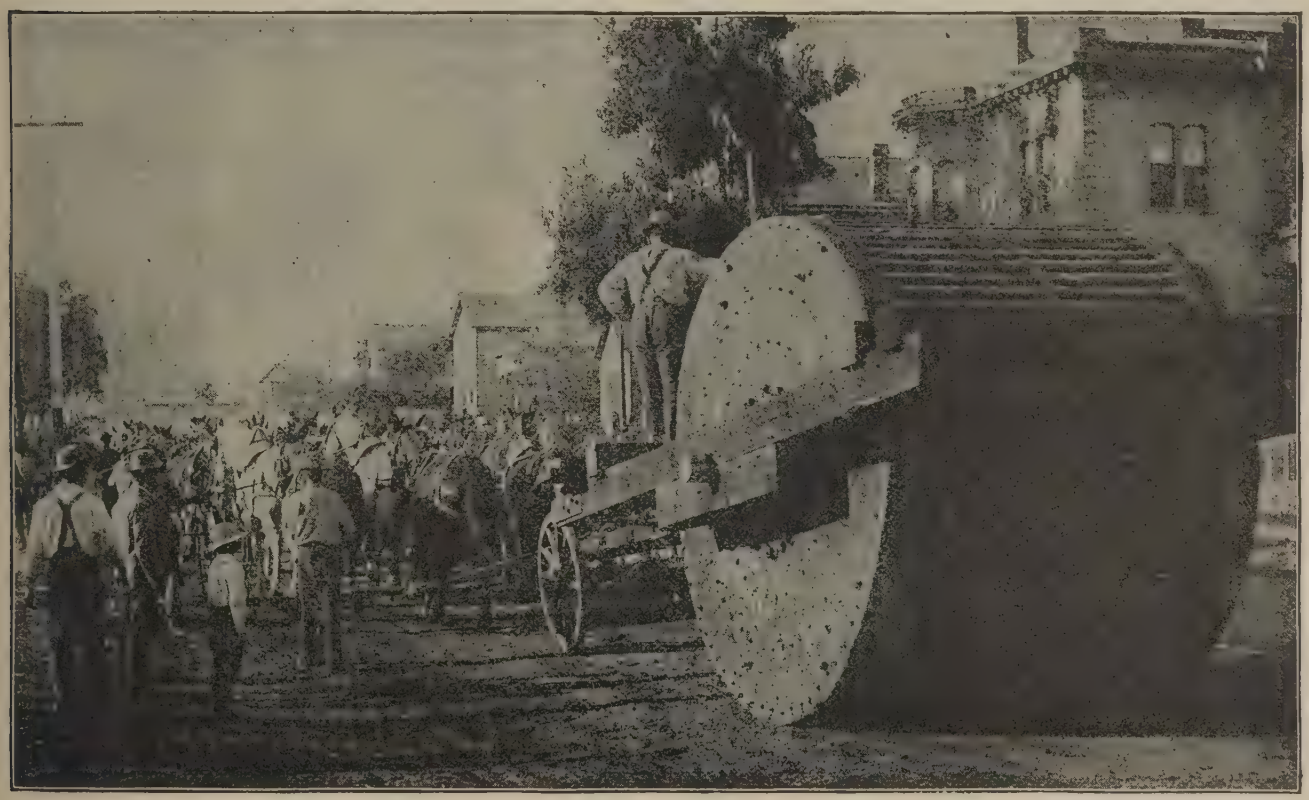


FIG. 231.—TRANSPORTING CABLE ON REEL.

Several methods are employed for stringing a rope in the conduit. If it is a new line it may be done by holding the end of the rope firmly in a grip, mounted on a car, to which a sufficient number of horses or mules are attached—from sixteen to thirty—to string it along the conduit. After half the length is run out a second car may be added, and other teams attached. In place of the grip and car a piece of half inch rope may be fastened to the end of the main rope, and this, coming up through the slot, provides for attaching the animals. Still another method is to provide a clamp having a thin, wide shank bent nearly to a right angle. This being fastened to the end of of the rope comes up through the slot and terminates in a suitable hook or ring for attaching the teams. When an old rope is to be removed, it is customary to cut this and splice the end of the new rope to it. The machinery is then started and the old rope as it runs out draws in the new one. For this purpose a dummy engine having a capstan is sometimes employed, and in a few instances small, special friction wheels are used for drawing out a worn rope. The old rope may be rewound upon a spool or, as is more frequently the case, allowed to coil itself in a heap in an open lot or yard. In this case it may be led out of the power house through a two or three inches iron pipe. Old ropes are usually sold to junk men and bring from six to eight dollars per ton. When a rope is to be placed on a new line the precaution should be taken to station signal men at

suitable intervals along the entire line, who being provided with signal flags or lanterns, and instructed in a signal code, are able to communicate with the head of the line, if it should be found necessary to stop for any purpose.

The rope having been strung through the entire length of the conduit, the ends are brought together, usually, at the power house, and after the rope has been laid over the winding drums and tension carriage it is ready for splicing. The operation of splicing a rope is one of the most important mechanical details connected with cable haulage, and an expert is usually employed for this purpose. It is a very simple operation, however, but requires care and precision, lest some variation in the size of the rope prove an element of destruction.

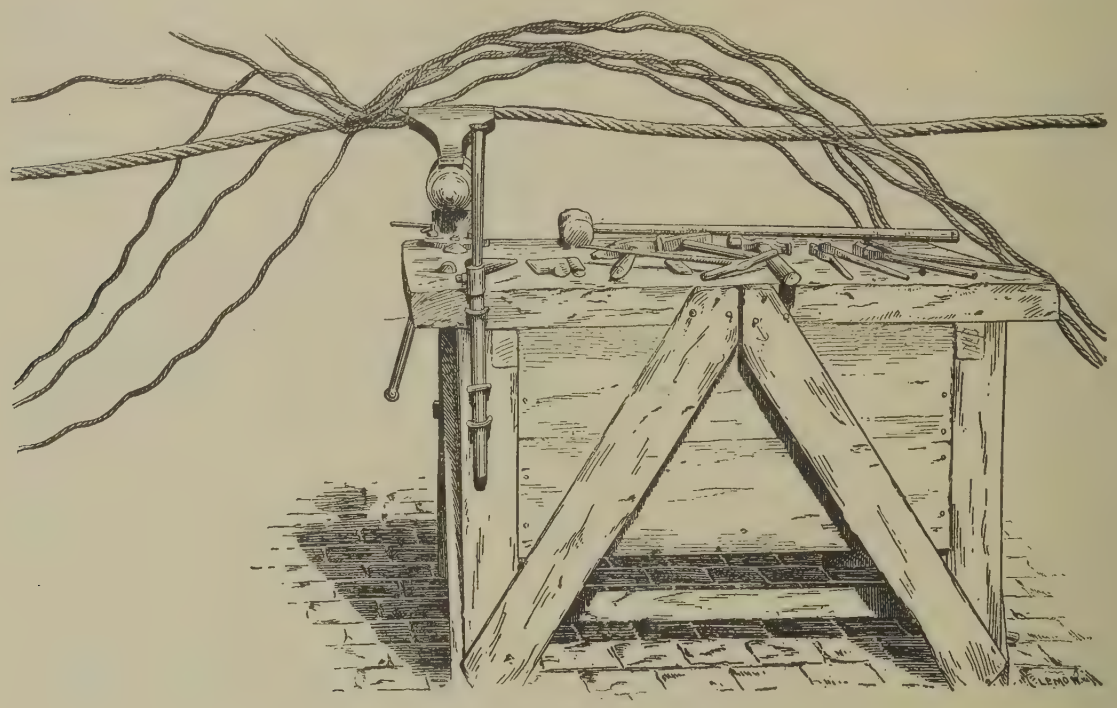


Fig. 232.

There are several methods of splicing a rope, each having special points of merit. The one most usually employed is known as the California splice and may be readily understood from the accompanying illustration and description. After being stretched to a proper tension the rope is cut to a suitable length, and the strands of each end are unwound for about thirty feet, and bound at that point with pliable wire so that the splice when completed will be sixty feet long. The hemp core is then cut out at the same point, and the solid ends of the core are brought together, the strands interlocking as shown in Figs. 232 and 233. The ends of the rope being known as A and B, strand number one of A is unwound back from the point of union, and strand number one of B is laid firmly and tightly in its place, leaving eighteen inches or more of its end projecting. Strand one of A is then cut, leaving the same length of end projecting (Fig. 234). Number two of A is then laid in place of number two of B, and the ends left as before. The other strands are then laid alternately in the same manner, but to a shorter distance, the ends being left equi-distant from start to finish, as shown in the last figure.

The next operation is to tuck the ends of the strands into the centre, a portion of hemp core being removed for the purpose To do this one end of the rope is clamped firmly in a vise and its strands are slightly separated, being untwisted by means of a small hemp rope and a lever, as shown in Fig. 235. A portion of the core being removed by cutting with a sharp knife, the ends of the strands, having been straightened, are crossed, and

by a peculiar shaped tool or pair of tongs (Fig. 236) and a dexterous twist of the hand, the end of one strand is tucked into the centre, and occupies the place of the hemp core. Any slight inequality can be taken out by pounding the rope with a

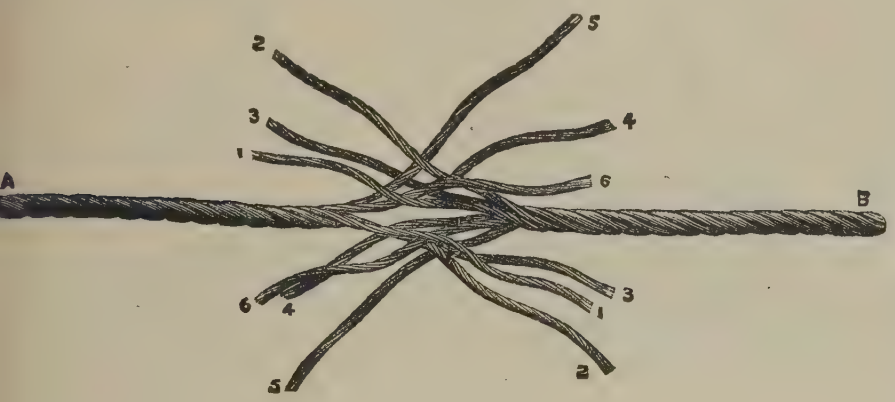


Fig. 233.

wooden mallet. The same operation is performed for the end of each strand, and when properly done it is hard to detect the place of the splice. In order to increase the holding capacity of a splice it is a good practice to wrap the ends of the strands, before tucking, with small annealed wire, canvas or marline. This not only keeps the wires in the strands from opening out but gives to the strand the same diameter as the removed core, causing the outside strands to grip the inlaid one firmly, and prevents the rope from shrinking at that point. Some splicers before tucking the ends of the strands cut away a part of the wires and taper off the ends of others, to prevent an enlargement of the rope at the point where the strands cross; others make all the wires tapering before tucking, a practice not recommended.

Another method of splicing a rope is known as the Chicago or Nash splice, and in practice gives excellent results. It is not practical, however, with the long lay pattern of rope. By this method the strands of the two meeting ends of the rope are alternately unlaid back to different points in the same manner as before described, but the method of securing the ends is quite different. The first step in the tucking operation is to untwist the outside wires of each strand and then to tie the untwisted ends of the strands in a single knot, as shown in Fig. 237, drawing it well down in the score of the rope, so that the knot will lie slightly below the regular circumference of the rope. The wires of the strands thus tied together are then untwisted back to the knot (Fig. 238), and the untwisted portions of each strand are passed under two of the strands of the rope at different points by means of a suitable tool (Fig. 239); the wires thus tucked and drawn through the rope are then cut off close to the surface, as shown in Fig. 240, and soon after the rope has been put in service it will appear as in Fig. 241.

A rope spliced by any method must be as strong as at any other point, but the operation must not increase its diameter. The operation being performed, the rope is endless and ready for service. The tools required for splicing a rope, as shown in Fig. 231, consist of a vise, marlin spike, wire cutters, pliers, cold chisel, hammers, wooden mallets, tongs and two rope nippers, with sticks to untwist the rope, etc.

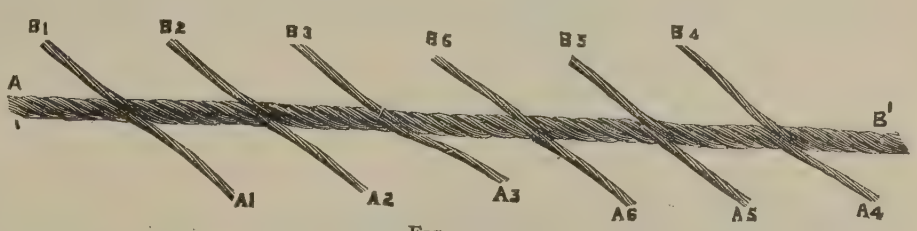


Fig. 234.

The operation of splicing is usually performed in the night, without causing delay to the operation of the cars It is sometimes necessary in the operation of a cable line to splice a section of new rope into an old one, but this should be avoided as far as possible, as it usually adds an element of danger. The strands of the new rope being slightly larger than those of the worn rope offer increased resistance in its passage through the jaws of the grip, especially if the grip happens to close, as the new

FIG. 235.

FIG. 236.

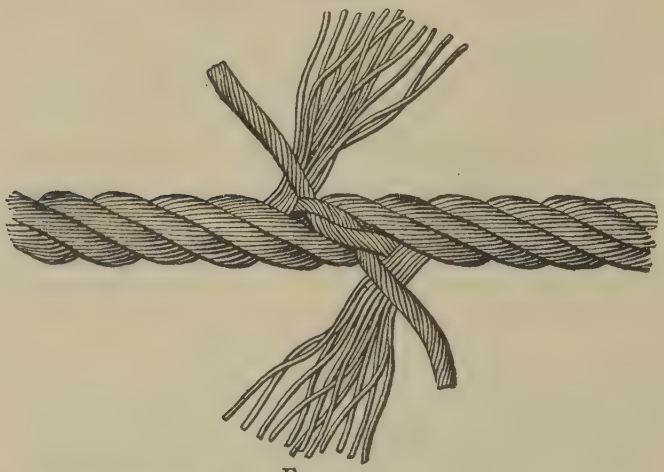


FIG. 237.

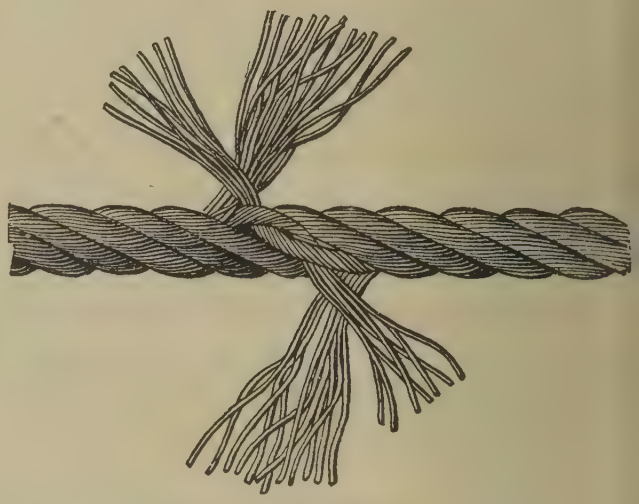


FIG. 238.

FIG. 240.

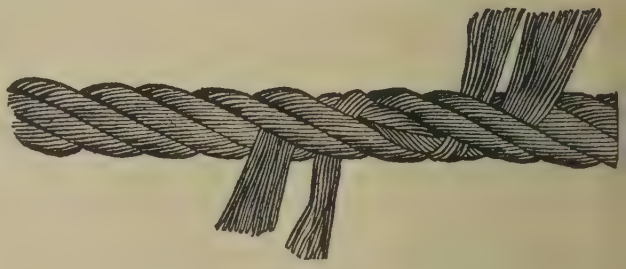


FIG. 239.

FIG. 241.

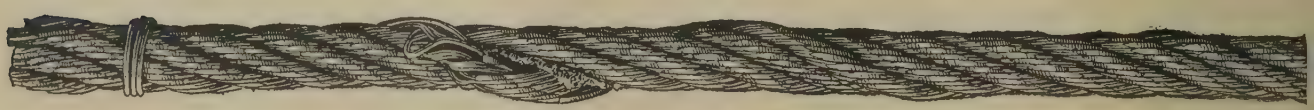


FIG. 242.

ortion of the rope approaches it. The increased ressure tends to draw out the tuck, and consequently, this strand will be slightly higher than the ther for some distance. As this operation continues, the accumulated slack of the strand will orm a loop or short kink back ten or fifteen feet from he end, and half an inch high, perhaps. Should he grip pass this point it would be likely to cut the rand, and the rope would have to be repaired. section of rope thus affected is shown in Fig. 242.

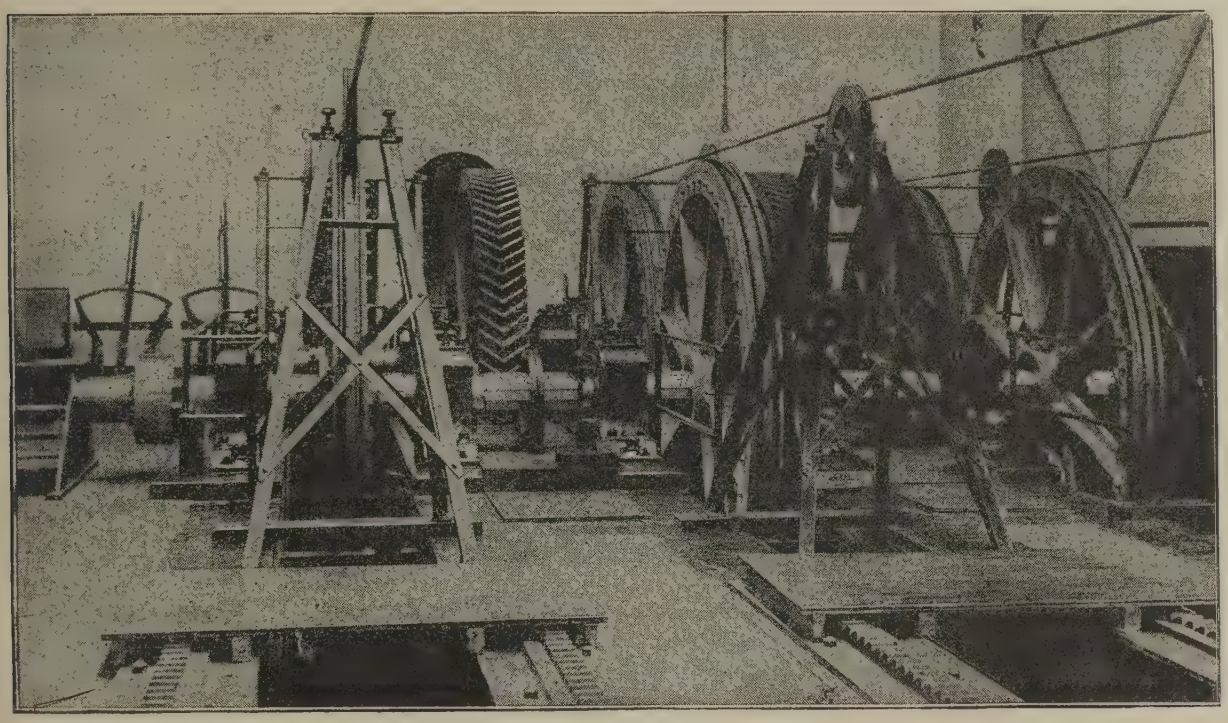


Fig. 243.—Rope Hauling Drums, S Drive.—Melbourne, Australia.

t is sometimes necessary when a cable is stranded o put in a single strand several hundred feet long. t is laid in and the ends are tucked in the same nanner as described for splicing.

As the rope becomes worn the danger of strandng increases and such a rope requires careful vatching. In a few instances wrecks have been caused by a loose strand or wire fouling the grip o that the gripman could not release his hold upon the rope, and the car, being driven forward, colides with other cars.

As soon as a rope is put in operation it should be reated to a coating of tar and oil or to a mixture of tar, oil, lime and mica. Suitable iron tanks are provided at the station in which the mixture is kept at a proper temperature and a very small stream is allowed to run continually upon the outgoing rope. The coating soon fills up the spaces between the wires and strands so that a working rope looks like a smooth iron rod or pipe. This coating serves to protect the cable from wear and causes it to slide readily through the grip jaws. Various compounds for a rope dressing are upon the market, but the best results are had with distilled tar without other ingredients. The special claim made for the patent dressings is that the material will not peel off during rain storms or in cold weather. with the rubber lined roller grips no lubrication of the rope is necessary.

THE DRIVING MACHINERY.

We find in the operation of cable roads that practice is by no means uniform in the devices employed for driving a rope continuously in one direction. On some of the earlier lines and on a few lines still in operation in our own country, as well as on nearly all foreign lines, the method illus-

trated in Fig. 243 is employed. Two large pulleys are provided having upon their peripheries V-shaped grooves in which the rope is made to take one or two wraps in the form of the letter S or figure 8, outlined in Fig. 244. These pulleys, in turn, are driven by means of suitable gear, as shown in

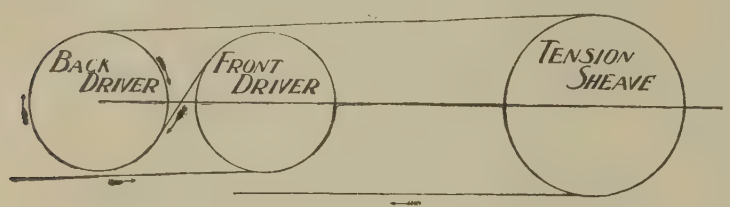


FIG. 244.—FIGURE EIGHT OR S DRIVE.

Fig. 243, and the rope, being held firmly in the grooves by means of the tension weight, is hauled by the frictional contact. The V-shaped grooves are usually lined with wood or babbit, but are sometimes formed with chilled iron blocks or clips as shown in Fig. 245. This figure also shows the method of attaching the clips to the surface of the pulleys. Fig. 243 shows three sets of pulleys for driving three ropes from the same station.

The most common method of driving, however, is shown in Fig. 246 and the following illustrations, Figs. 247 to 250, which are modifications of the general method employed in Fig. 246. This same figure also illustrates the relation of the driving machinery to the track and cars. By this system the rope is caused to make several direct wraps about two winding drums having in their faces shallow grooves of the same form as the rope. These drums are set slightly inclined to the right and left from the perpendicular, so that certain grooves on each are brought in line with each other, and as the rope leaves the groove of one it passes directly into the corresponding groove of the other. This arrangement of two drums set in line is required from the fact that with only one drum the rope would wind on in the form of a spiral or screw thread and travel sideways off from the surface. With the above arrangement, however, the rope is led directly from groove to groove and always enters and leaves the drum at the same point. It will be observed from the accompanying illustration, except Fig. 249, that the winding drums are mounted overhanging at the end of a shaft, the outside bearing being supported by a truss merely. The object of this is to facilitate placing the rope upon the drums after it has been spliced, and also to provide for putting an additional wrap upon the drums as the rope stretches. The diameter of the winding drums is usually about twelve feet. It may be larger, but should not be much less, although, with the S drive, they are ordinarily only eight feet in diameter. A safe rule is to make the winding drums and all guide sheaves over which the rope bends at least 100 times the diameter of the rope. It is frequently necessary to drive a number of ropes at different speeds from the same shaft; this is accomplished by varying the diameter of the drums. Speed, however, is the only advantage to be gained by the employment of drums having a larger diameter than the minimum. No more force can be imparted to the rope by means of a larger drum, for it will require that the same number of wraps be made about the larger drum to secure the required contact as about the smaller, as the co-efficient of friction depends not upon the

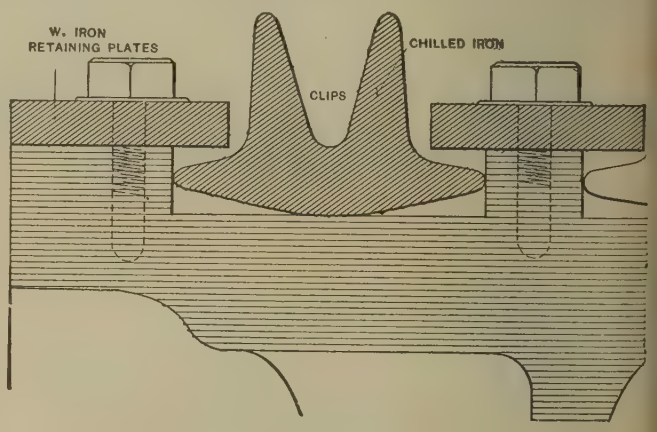


FIG. 245.

length of the arc upon which the rope rests, but upon the pressure per square inch, the speed, and the material with which the grooves are lined.

The frictional contact between the rope and driving drums is maintained by means of a tension apparatus, illustrated in Fig. 251. This device consists, usually, of a large sheave mounted upon a car, which is arranged to travel back and forth

upon a track laid over a long, narrow pit. To this car is attached a tail rope or chain, which is led over a pulley suspended within a deep well, and fastened to a heavy weight. This car is free to move back and forth upon its track as the load upon the rope varies, and not only maintains the necessary tension, but also takes up the slack as the rope stretches, and provides, further, for the expansion and contraction of the metal from heat and cold. The length of track to be provided for the tension carriage depends somewhat upon the length of rope operated, from 150 to 200 ft. on long lines. The car is usually provided with a windlass, operated by a hand wheel and worm gear for adjusting the length of the tail rope.

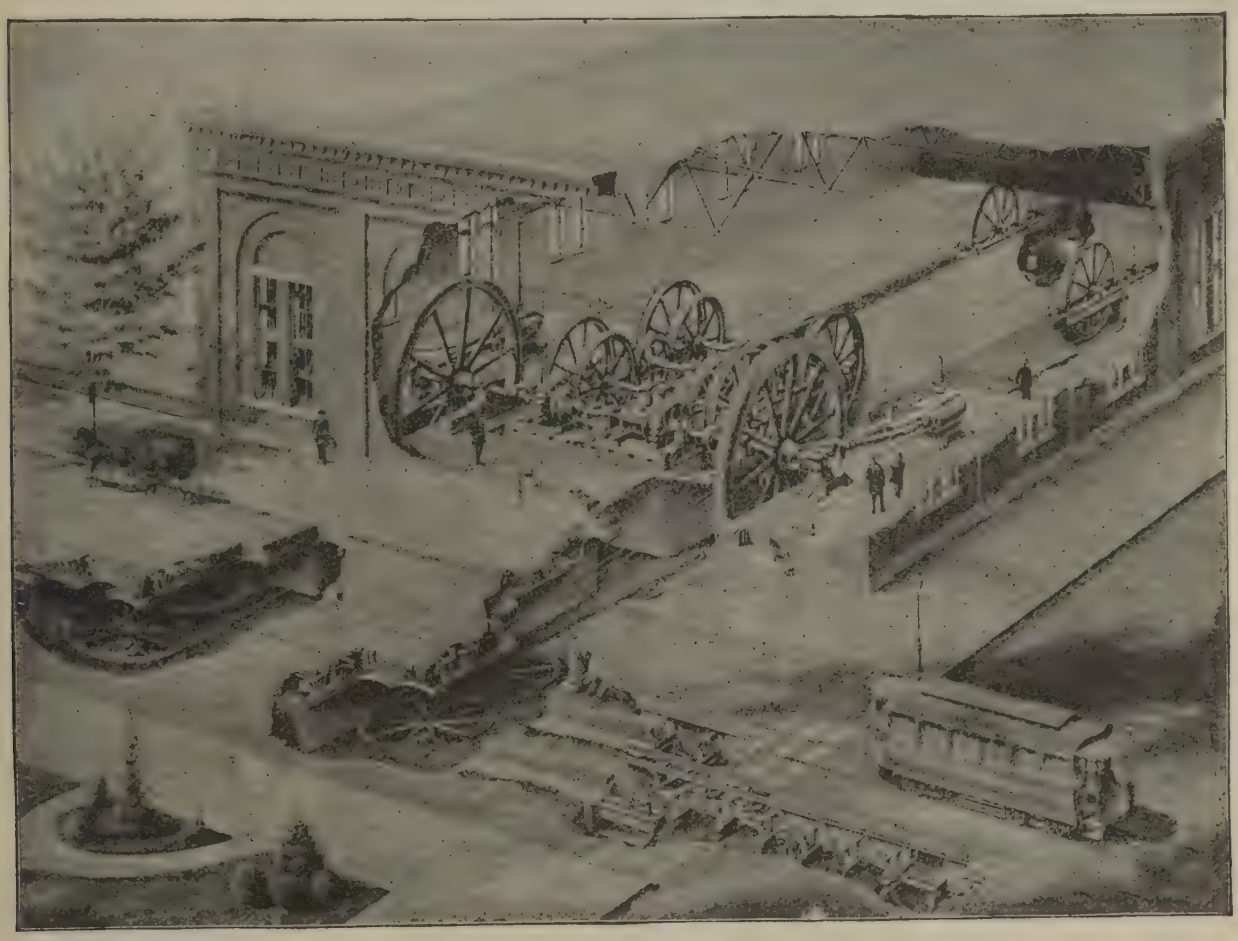


FIG. 246.—CONVENTIONAL DIAGRAM OF CABLE POWER PLANT.

Other forms of tension carriages, each having peculiar advantages, are shown in Figs. 252 to 256. The first consists of a double car, or one car resting upon another. The tension pulley is mounted upon the smaller car, which has a limited motion back and forth upon the larger car, controlled by the weight which in turn is supported upon the long car, and this car in turn is anchored in place by means of a hook and rack, or by means of a stout rope and tackle blocks. When the rope stretches so that the tension car runs back against the rear buffers of the long car, this, in turn, is moved back till the former assumes the position shown, and is free again to give and take.

Both the cars are readily moved back while the line is in operation, by means of a block and fall. The power to do this is obtained from the moving rope by having a capstan on the end of the shaft of the tension car, around which the hauling rope of the tackle is wound, and then held fast. As the capstan revolves the rope is wound up, and the

car moves back. Fig. 253 illustrates a second form of double car, admirably adapted for use on a light line, by the use of which the expense of a long pit is avoided. As will be seen from the figure, this double carriage travels on an ordinary track, and carries the tension weight entirely in the carriage body, and is thus independent of a pit. In connection with this same device the use of a rail dog for holding the carriage is recommended in place of the rack and ratchet arrangement usually employed. This dog consists of a cam arranged to bite the rail the instant there is any pull along the holding rod from the carriage (Fig. 204). Two of these dogs, being attached to the carriage, one on each rail, will hold it securely in place, and should it be necessary to back the carriage further away from the winders, the cams free themselves, and the dogs are pushed along without attention.

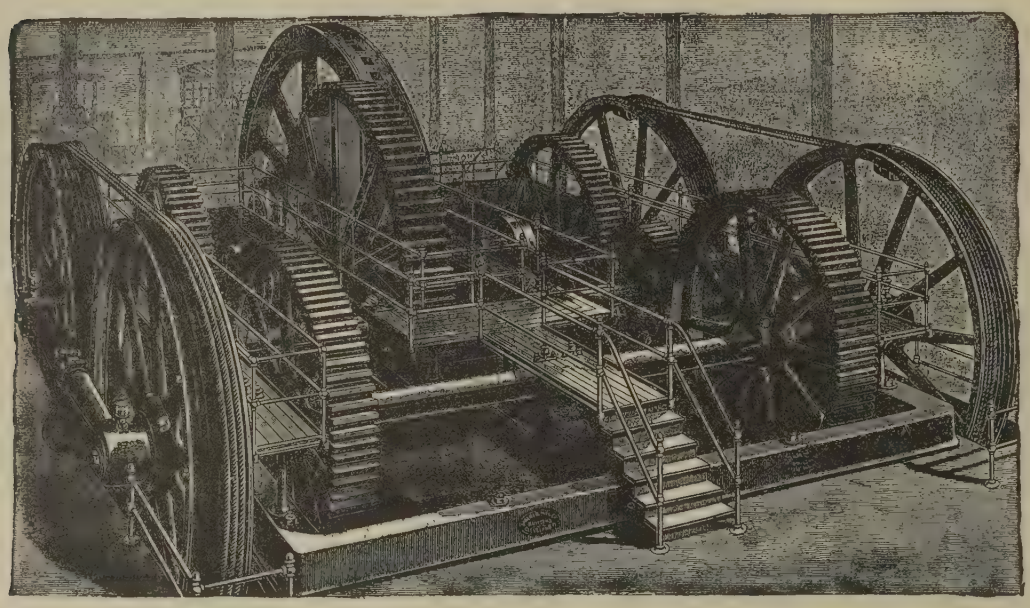


FIG. 247.—ROPE WINDING DRUMS, INTERMEDIATE GEARING AND DIFFERENTIAL RINGS.

Fig. 255 illustrates one type of tension car which allows of the rope being operated under a very light tension. A supplemental weight is provided as shown, and so hung that when an undue strain comes on the rope, it is lifted and adds its weight to that of the tail weight, and the higher it is lifted the greater becomes its back pull upon the car. The same figure illustrates a method of suspending the tail weight, by which the necessity of a deep well is avoided. The same principle is employed in Fig. 256, which illustrates an interesting and practical type

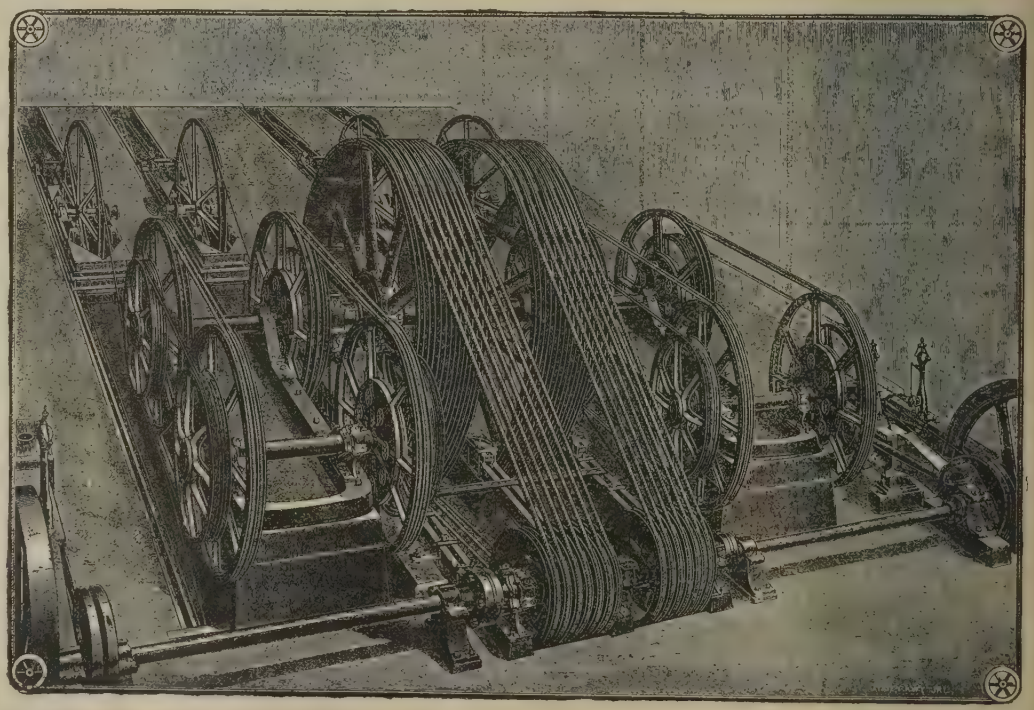


FIG. 248.—WINDING DRUMS, COTTON ROPE DRIVE AND ROPE GEARING—LOS ANGELES, CAL.

of tension carriage in which the entire weight is suspended upon jointed arms, which are attached to rocker shafts, one being stationary and the other mounted upon a small iron truck to which the tension carriage proper is anchored by wire ropes. Fig. 256A is a diagram illustrating the value of the weight in different positions. In case it is desirable to graduate the weight on ordinary rope by gravity. This arrangement, however, is not as prompt in action as the other, and it is not often convenient to construct an incline of sufficient length to provide for the necessary slack. It is thought by some to be of advantage to supplement the station tension on long lines, by providing a tension carriage at one or both terminals, in which case inclines are generally employed, as they are

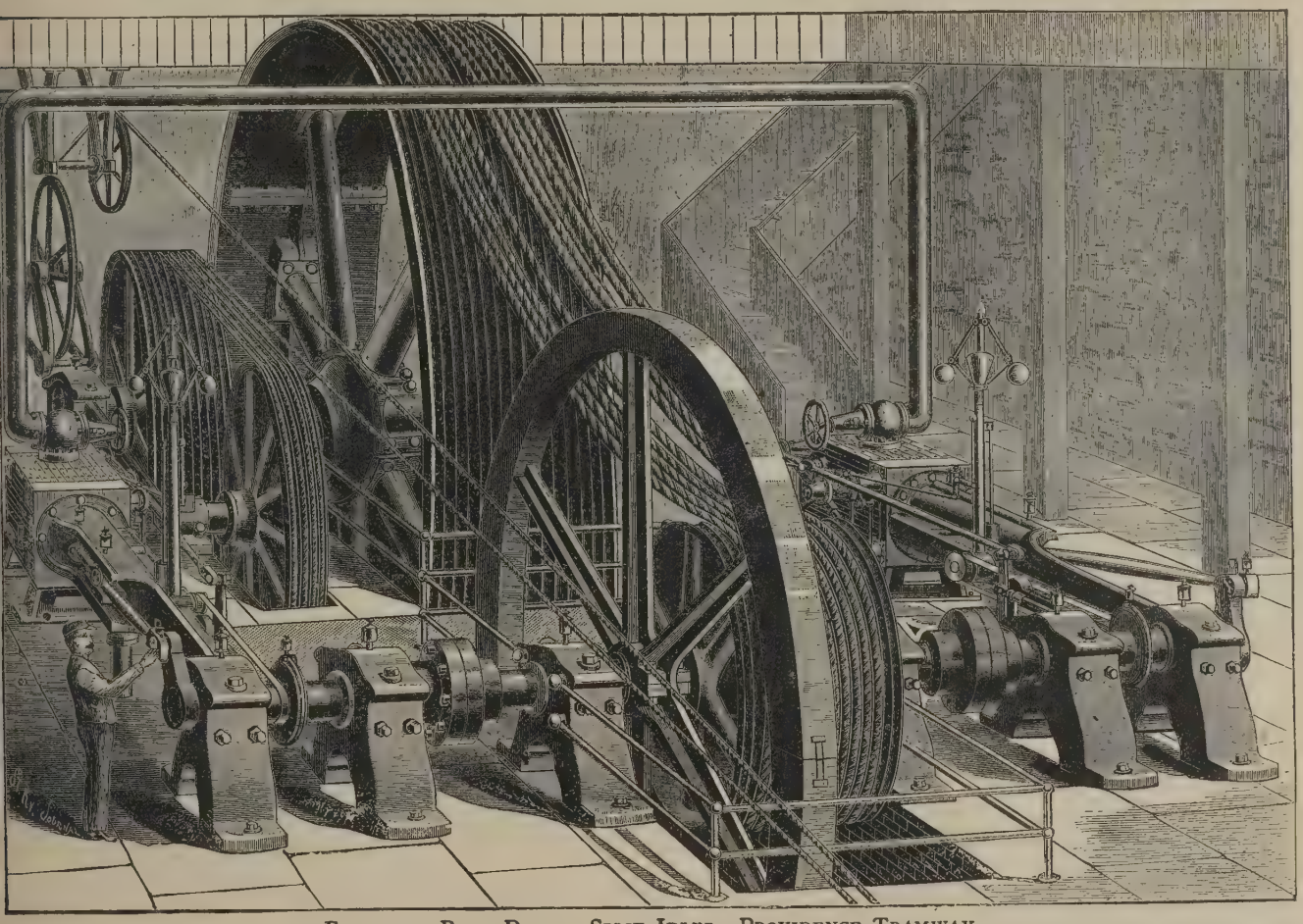


FIG. 249.—ROPE DRIVE—SPLIT IDLER—PROVIDENCE TRAMWAY.

carriages, it may be done by having projecting lugs cast upon the sides of the iron plates composing the tail weight; then as the weight descends, one plate after another rests upon shelves arranged in the sides of the well, relieving the rope of undue strain. As the rope again runs out and lifts the weight, one plate after another is added to it.

Instead of a car controlled by tail weights, a weighted tension carriage is sometimes mounted upon an inclined track, so that it operates upon the also in connection with the machinery for operating an auxiliary rope. No definite rule can be given as to the amount of tension that should be put upon a rope to secure safe and economical driving. Generally speaking, only so much weight should be employed as will prevent the rope from slipping on the driving drums, as the less tension the less power it requires to drive the rope, and the longer its life. Some advocate a taut rope to prevent the surging motion of the cars, but this motion is not very objectionable, and were the pro-

posed remedy a sure one it would not compensate for the extra wear upon the rope. The type of winding drums, whether solid, differential or S, with one or both driven, and the number of wraps, influence the amount of tension. In settling the question as between extra tension and an extra wrap, to enable a rope to do its work without slipping, it will be necessary to consider the character of the line. On a comparatively straight road the advantage would seem to be in favor of an extra tension, but on a line with numerous curves it would be in favor of an extra wrap. The best practice favors as few wraps and as light tension as possible.

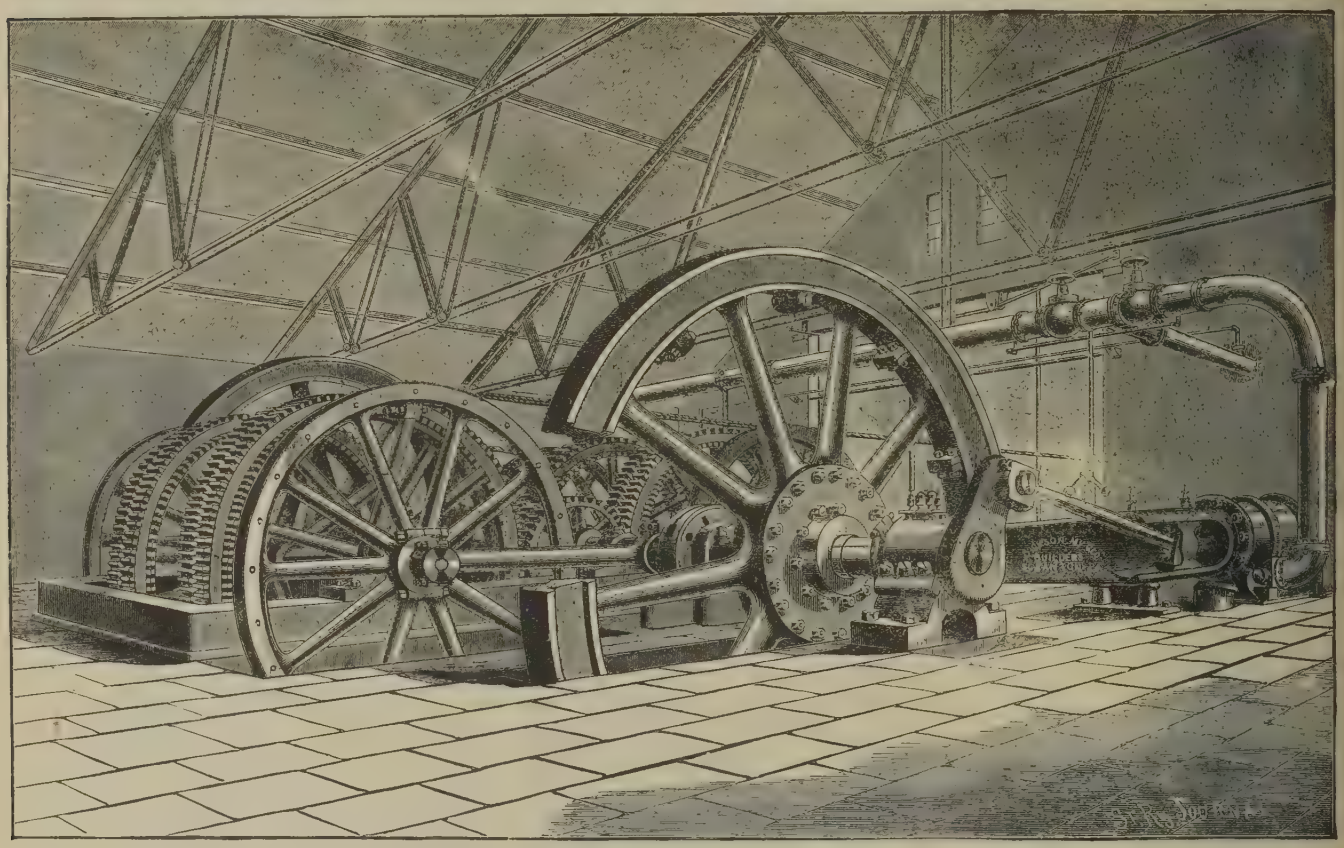


FIG. 250.—INTERMEDIATE GEAR ON MAIN SHAFTS—BROADWAY LINE, ST. LOUIS, MO.

Reverting to rope driving apparatus, we find, as before stated, a variety of methods. The S or Fig. 8 method, illustrated in Figs. 243 and 244, is objectionable because in making the wraps a reverse bend is given to the rope, tending to its ultimate destruction. Still, in some cases, very good results have been obtained by this method. Solid drums geared together so that each assists in driving the rope, have been quite extensively employed, but there is an objection to this method of driving, from the fact that the grooves in which the rope runs are liable to wear unevenly, in which case a given length of rope is required to cover arcs of different diameters. Still, practice demonstrates that solid drums where properly designed and operated have performed great and continued service without wearing differently to a marked degree. Usually, the first groove or the one that receives the incoming rope wears the fastest; then in case the second groove has a larger diameter than the first, the rope must stretch or slip in order to cover it, and if the third is still larger there is a good deal of slipping, and the rope is injured both by the slipping and by the excessive strain, and as the action continues the grooves are worn still deeper, increasing the defects. This difficulty may be remedied in a measure by occasionally turning out the grooves, making the diameter of the second

a little less than the first and the third less than the second, or by shifting the rope from one side to the other on the drums, so that the rope may enter the grooves in the reverse order.

Sometimes the relation of the diameters is changed by an accumulation of tar and dust in the bottom

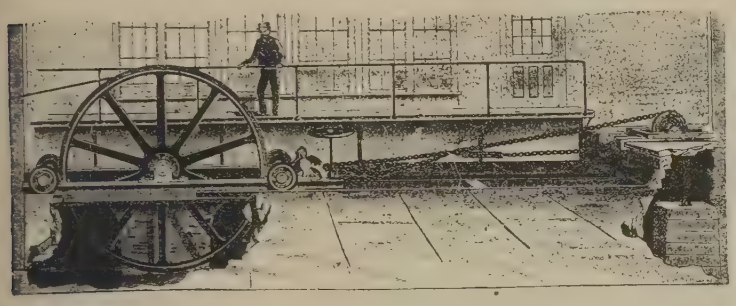


FIG. 251.—TENSION CAR.

of the groove. This may be prevented, however, by placing scraping tools to one side of the drums with their ends ground to nearly fit the form of the of the grooves.

Besides the wearing action between the rope and groove due to the unequal diameters of grooves, both rope and groove are subject to wear from the creeping of the rope in the individual grooves, due to the unequal strain to which the different wraps are subject. Each section of rope leaves its individual groove, successively, under less strain than when entering, until the last, when it sustains only the strain imposed upon it by the tension weight. As the strain is gradually reduced the rope contracts, producing a slight creeping motion within the individual grooves.

In order to obviate the difficulties attending the operation of solid drums as above enumerated, devices of various kinds have been employed, one of the most popular of which is illustrated in Figs. 247 and 257, and consists in fitting to the surface of the drum loose rings in which the individual grooves are formed. The rings are held together with the required pressure by means of an adjustable flange, and the pattern is known as the "Walker differential ring drum." With this device, in case the grooves have an unequal diameter or the wraps are subject to any unequal strain, the rings tend to slip upon the face of the drums and thus relieve the rope of any undue strain without chafing it. Provision is made for lubricating the surfaces between the rings and drum by oil cups placed under the rings as shown in Fig. 257.

An attempt to produce the same results as are obtained by the use of the differential rings has been made by driving with one solid drum, and from this leading the wraps each over separate idlers, mounted loose on the same shaft so that they revolve independently of each other. (Fig. 249). Another method designed to correct the unequal strain put upon the different wraps is illustrated in Figs. 258 and 259, and although extensively used it does not, in the opinion of many engineers, accomplish what is intended. In Fig. 258 the arms of the drum are broken away showing only the differential mechanism. Each drum is cast in two parts with dishing arms or, rather, is made up of two sheaves having two or more grooves in each, mounted loose on the shaft, but in position to bring the inner faces of the rims together. These sheaves are driven from the main shaft by means of

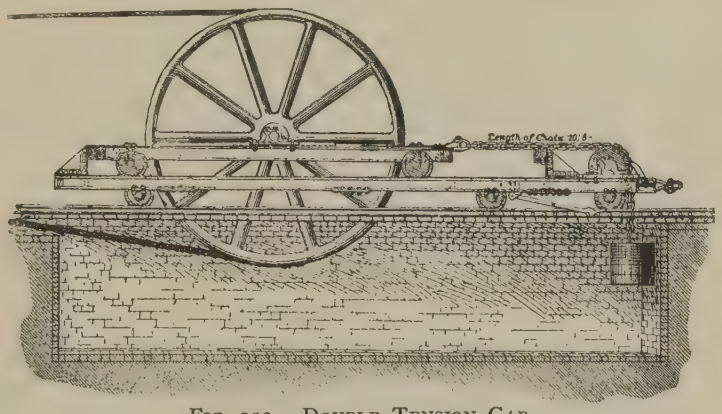


FIG. 252.—DOUBLE TENSION CAR.

small horizontal beveled gears, journaled at right angles to the main shaft and meshing into gears on the inner faces of the sheaves. The wraps being equally divided on each side of the split rim the independent sheaves can change their relation to each other, depending upon the tensions of each set of wraps, the beveled gear turning slightly in

the direction of the hardest pull. A method of connecting the drums is illustrated in Fig. 260, the object being to get equal work from the drums without the intervention of rigid gear.

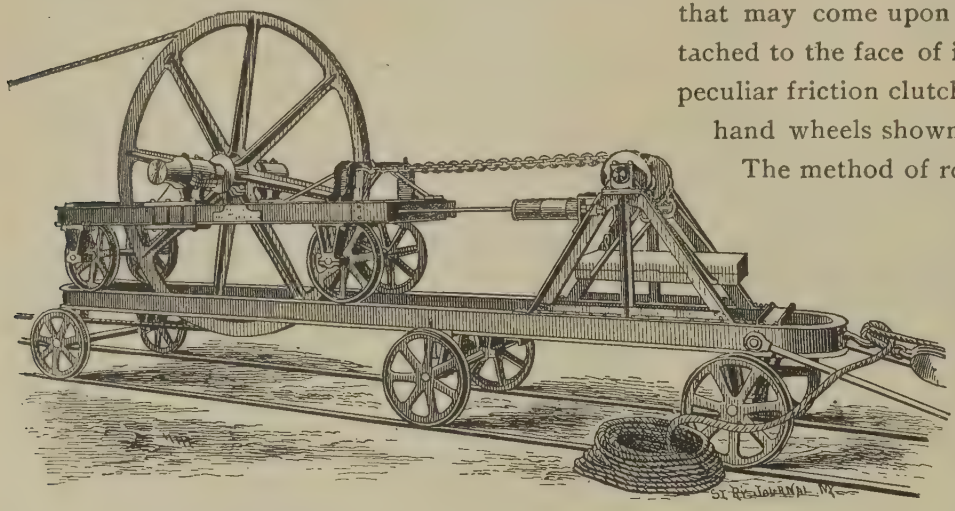


FIG. 253.—DOUBLE TENSION CARRIAGE—SAN DIEGO CABLE TRAMWAY.

Both drums, it will be seen, are driven by independent pinions which run loose on the main shaft, but are actuated by small horizontal beveled gear wheels, which are mounted on each side of the main shaft on bearings at right angles to it and mesh into the sides of the pinions in about the same manner as before described for the split drums. By this means one drum is at liberty to travel faster or slower than the other as the distribution of the strains may require. In order that, under the usual conditions of service, the drums may perform equal work, deflection sheaves are placed to the left, as shown, upon which the incoming and outgoing ropes are led, the sheaves being mounted loose on the shaft so that they run in opposite directions. The position of this shaft should be parallel to the main shaft in the same plane, and at a certain distance from it.

Fig. 248 illustrates a novel method of driving, in which cotton ropes are employed for transmitting the power to the drums in place of solid gear, and in which the drums themselves are connected by means of cotton ropes. The cable drums, it will be seen, are mounted on the faces of large pulleys which have grooves for two cotton ropes. One of these rope pulleys is made a trifle larger in diameter than the other to make sure that the idler is driven by the cotton ropes and not by the cable. To provide for any unequal work that may come upon the cable drums, each is attached to the face of its rope pulley by means of a peculiar friction clutch, which is adjusted by small hand wheels shown on the face of the drum.

The method of rope transmission renders the operation of the machinery noiseless, a very desirable object in any power plant.

Fig. (250) illustrates a method of driving both drums by the employment of a single pinion and gear, the main shaft being placed as shown, between the drums with the engines at either end. By this arrangement the principle of the overhanging drums need not be sacrificed, even though several pairs of drums are driven from the same shaft. To accomplish this, however, it is necessary to mount the main shaft in sections with disks and key couplings to unite the sections,

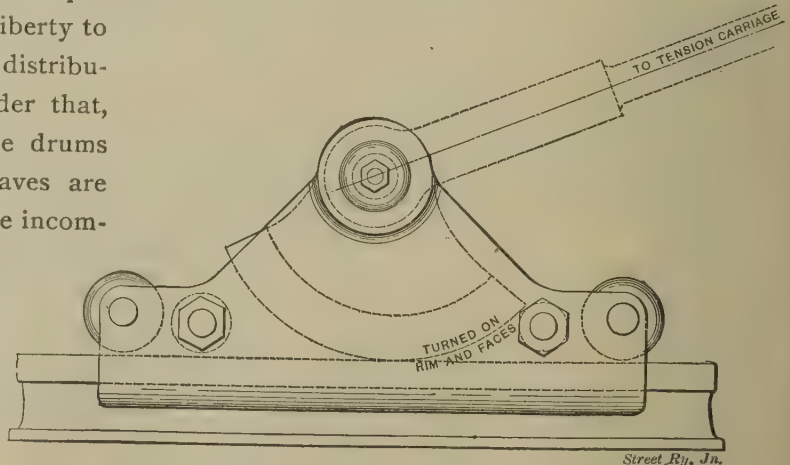


FIG. 254.—RAIL DOG FOR TENSION CARRIAGE.

sufficient space being left between the terminals, after the key is removed, for the passage of the rope when it is necessary to add an additional wrap. In this particular plant mortised gears are employed, and the teeth are set in echelon and the drums are equipped with the differential rings.

ther plants with the shaft in the same position, mploy cut or cast gear with satisfactory results.

work is unusually heavy and duplicate cables are employed, in order that the line may be operated

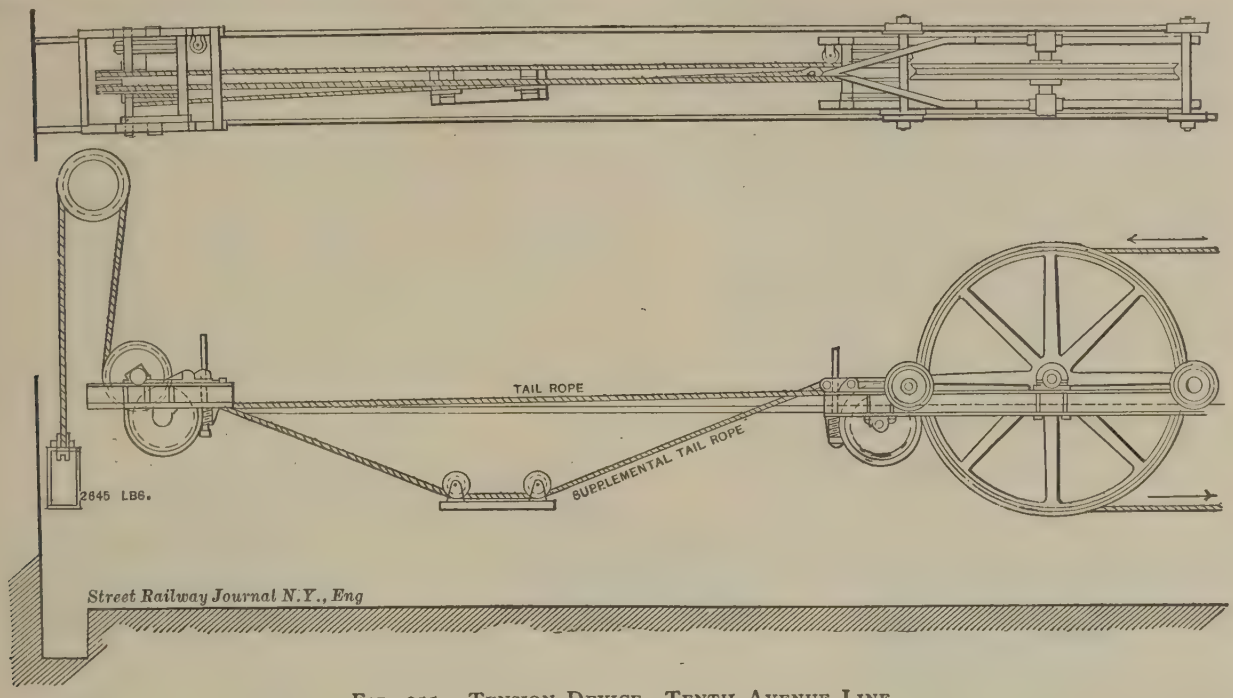


FIG. 255.—TENSION DEVICE—TENTH AVENUE LINE.

A design which combines both rope transmission and intermediate gear, is illustrated in Fig.

day and night, without the necessity of interrupting the traffic for repairs. The position of the en-

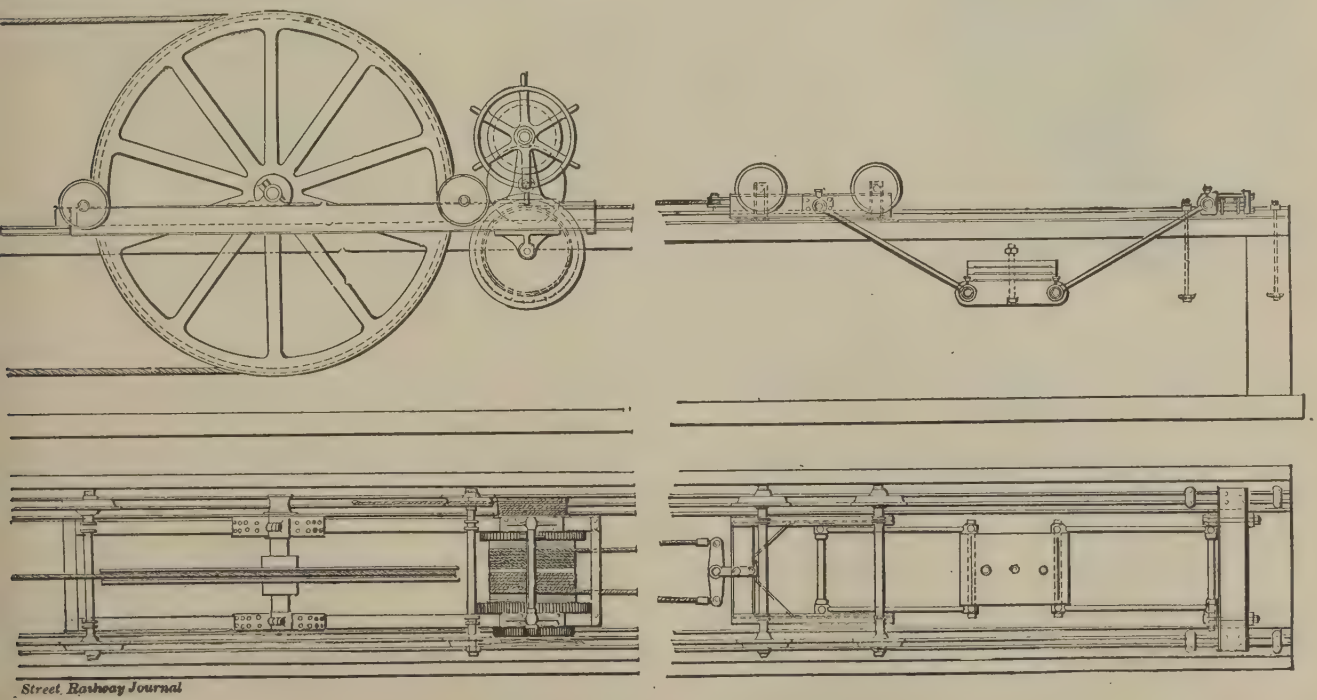


FIG. 256.—SIDE ELEVATION AND PLAN OF CABLE TENSION APPARATUS.

261, the drums being connected by solid gear. This arrangement is employed on a line where the

gines and the arrangement of friction clutches in the shafting are such that, either one, two or all

the engines may be made to drive either set or all of the drums, the speed of the different cables being governed by the diameter of the drums.

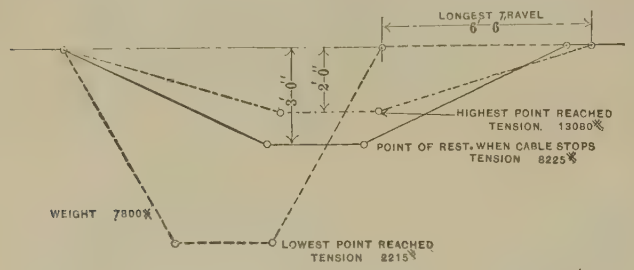


FIG. 256A.—SHOWING POSITION AND VALUE OF WEIGHT.

A similar arrangement on a larger scale is shown in Fig. 262. Figs. 263 and 263A show a method of rope drive without intermediate gear, both drums being driven from the same pinion by means

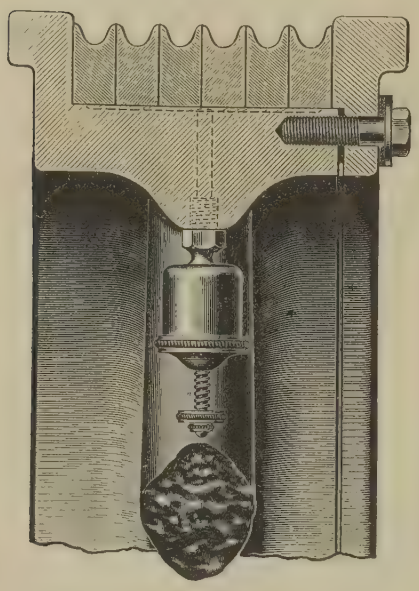


FIG. 257.—SECTION OF DIFFERENTIAL RING DRUM.

of rope sheaves mounted on the shaft of each drum. The construction and arrangement of solid drums is frequently modified for economical purposes, or to conform to the conditions of limited space. Fig. 249 illustrates a wide faced drum having an extra set of grooves, so that when one set of grooves becomes worn the drum may be shifted sideways on its shaft and the rope transferred to the unused grooves, thus doubling the life of the drums. A removable rim containing the grooves is sometimes applied to the face of the drums (Figs. 264 and 265) so that when the grooves are worn the rims may be renewed without discarding the entire drum. The rims are cast in sections and are bolted together and to the face of the drum, as shown.

In some cases where it is necessary to economize space the drums are placed one above the other, as shown in Figs. 266 and 267, which may be driven singly or coupled by gearing, as when in the ordinary position. The incoming and outgoing ropes being led to and from the lower drum, the latter is readily conducted to the tension sheave, in the same manner as with the drums on the same level.

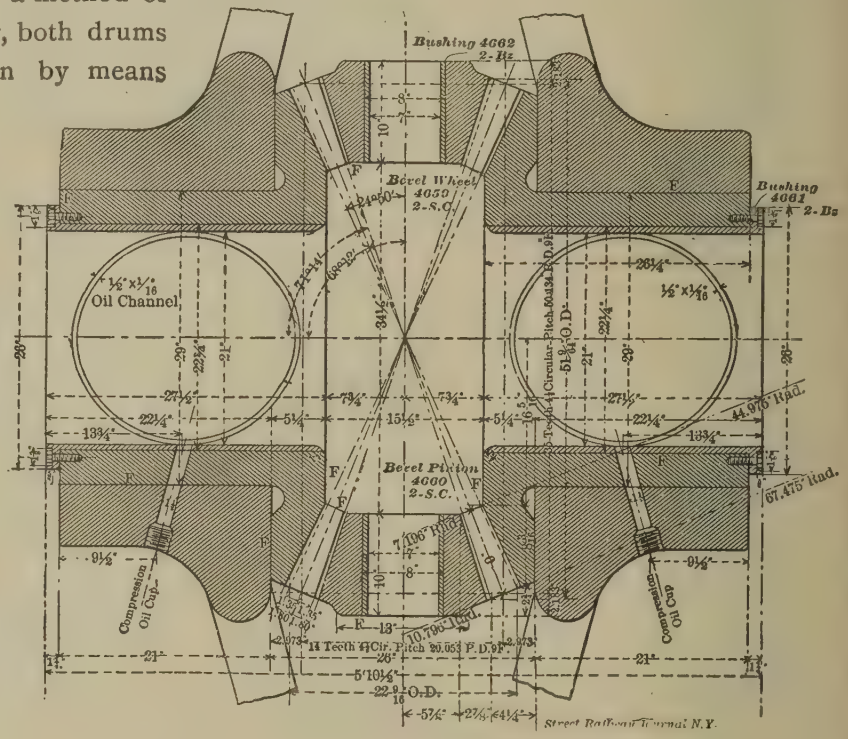


FIG. 258.—WHITTON COMPENSATING GEAR.

It is claimed, that with drums in this position the rope is less liable to slip in the grooves, as the weight of the rope tends to increase the frictional contact.

AUXILIARY DRIVE.

In some cases it is found necessary to operate a loop or some portion of the line by an auxiliary cable running at a slower speed than the main cable, in which case, when the section is too far away to be operated from the power house, auxiliary driving machinery, having drums similar to those used in the driving plant, is employed which

may be located in a pit under the street (Fig. 268), the roof of which is supported by steel I beams covered with brick and cement. In the case illustrated, the main cable running at twelve miles per hour, is led over the drums shown at the left of the figure, thence to a terminal sheave and back to the power station conveying its power by means of the intervening pinions and gears (four and ten feet in diameter respectively) to the drums on the right, about which the auxiliary rope is led, thence to a tension carriage mounted on an incline at one end of the pit and thence into the conduit at a reduced speed.

SELECTION.

From the foregoing it will be noted that there is a great diversity of opinion among engineers as to the proper method of driving ropes for cable haulage. Theory amounts to but little in this business where it is not confirmed by long practice. Each new line presents new problems and the judgment of the engineer must govern in the selection of the type of drum to be employed and the method of gearing, first having learned the true history of as many plants as possible, already in operation

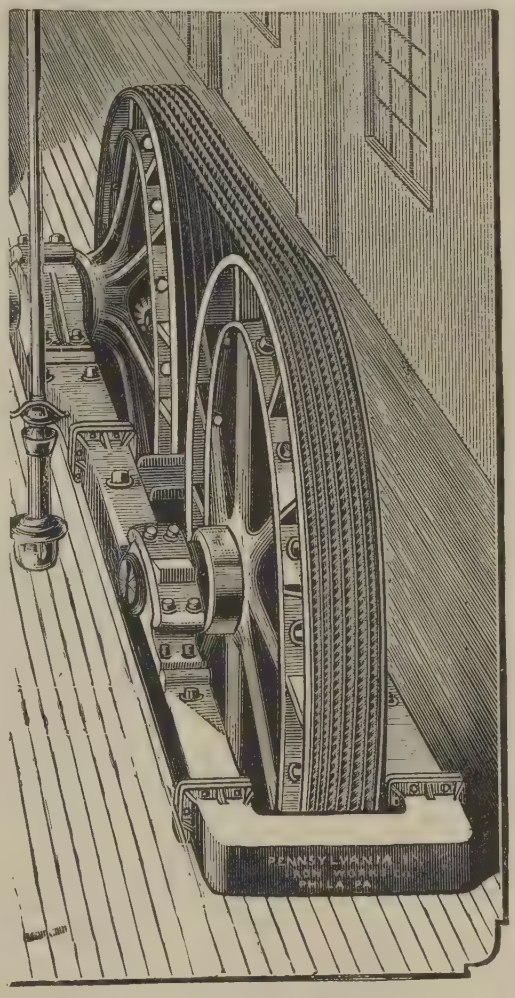


FIG. 259.

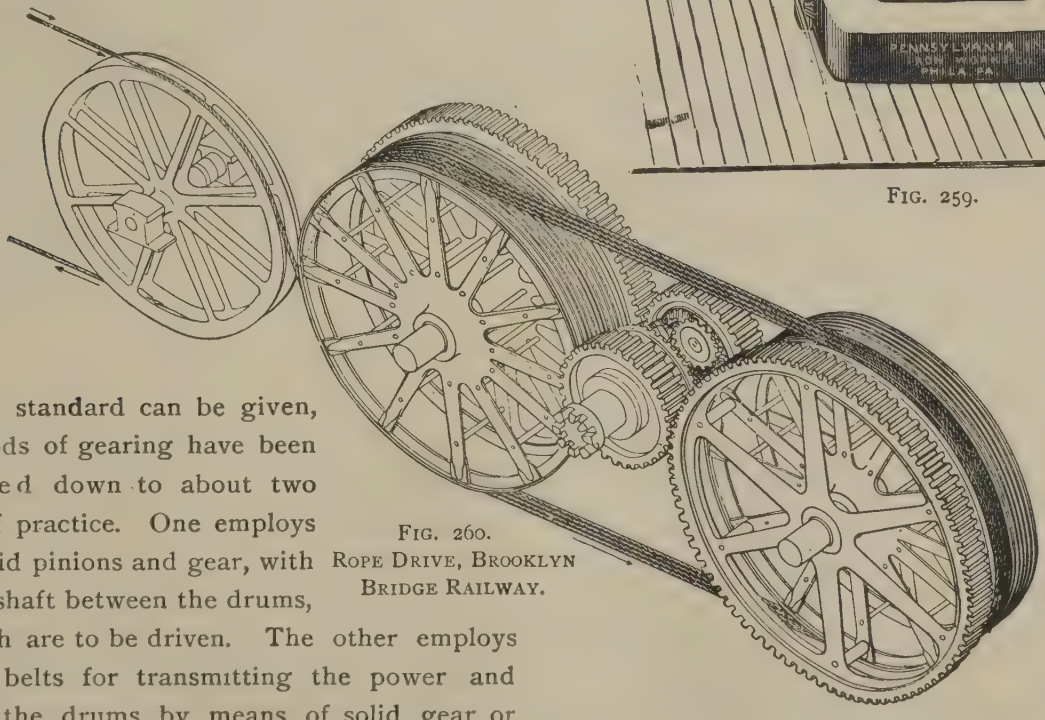


FIG. 260.
ROPE DRIVE, BROOKLYN BRIDGE RAILWAY.

While no standard can be given, the methods of gearing have been narrowed down to about two schools of practice. One employs single solid pinions and gear, with the main shaft between the drums, when both are to be driven. The other employs ropes or belts for transmitting the power and connects the drums by means of solid gear or ropes, the former being generally preferred. In either case solid or differential ring drums may be used. The weight of testimony is in favor of the latter.

In making a selection of drums and gearing, the following questions stated in the order of their importance, must be considered: Reliability, dura-

bility; power required; effect upon the rope; noise and cost. The employment of mortised or of helical gear, introduces an element of weakness that should be avoided. While the wooden gear is desirable, in that it is nearly noiseless in operation, the teeth are liable to shrink and break, requiring to be frequently renewed, and not infrequently interrupting the traffic. The helical gear is undesirable, in that it communicates a shuttle motion to the shafts, causing the shoulders at the bearings to wear and imparting a vibratory motion to the foundations which tends to unsettle and destroy them. By reducing the number of gears, less power is required to operate the drums, and, other things being equal, the plant is more durable. The effect upon the rope has already been considered. It is important to eliminate the noise, and this may be accomplished by the employment of ropes or belts, or by introducing into the foundations some non-vibratory material, and by cutting off the foundations from the walls of the building. The cost—within reasonable limits—should not govern, provided a reliable plant is secured.

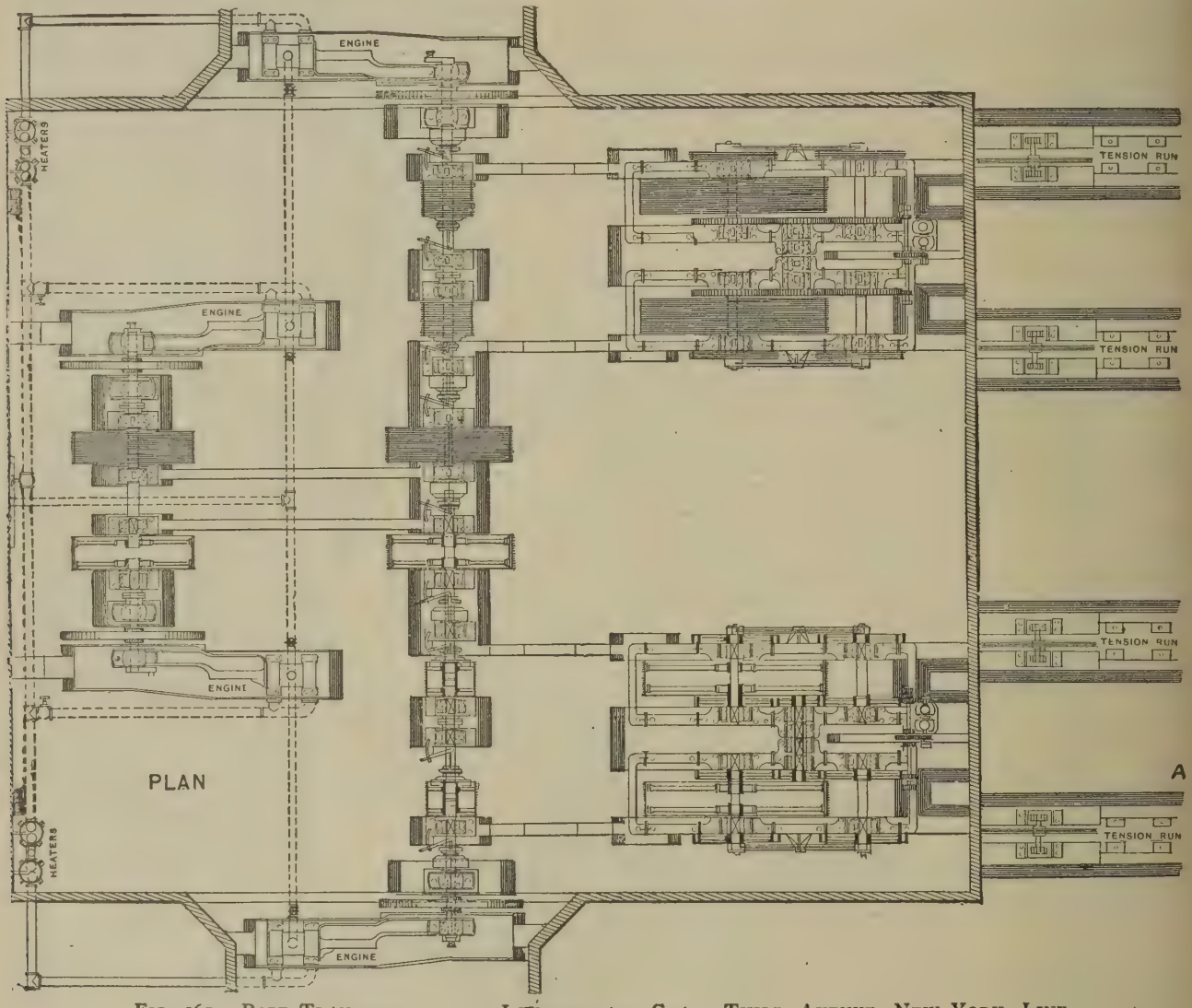


FIG. 261.—ROPE TRANSMISSION WITH INTERMEDIATE GEAR—THIRD AVENUE, NEW YORK, LINE.

HAULING POWER.

The hauling power of a pair of winding drums depends upon the following conditions: Whether one or both drums are driven; the tension on the outgoing line; the friction of the rope, and the length of the arc of contact in the grooves.

Since the total stress on the wraps about the

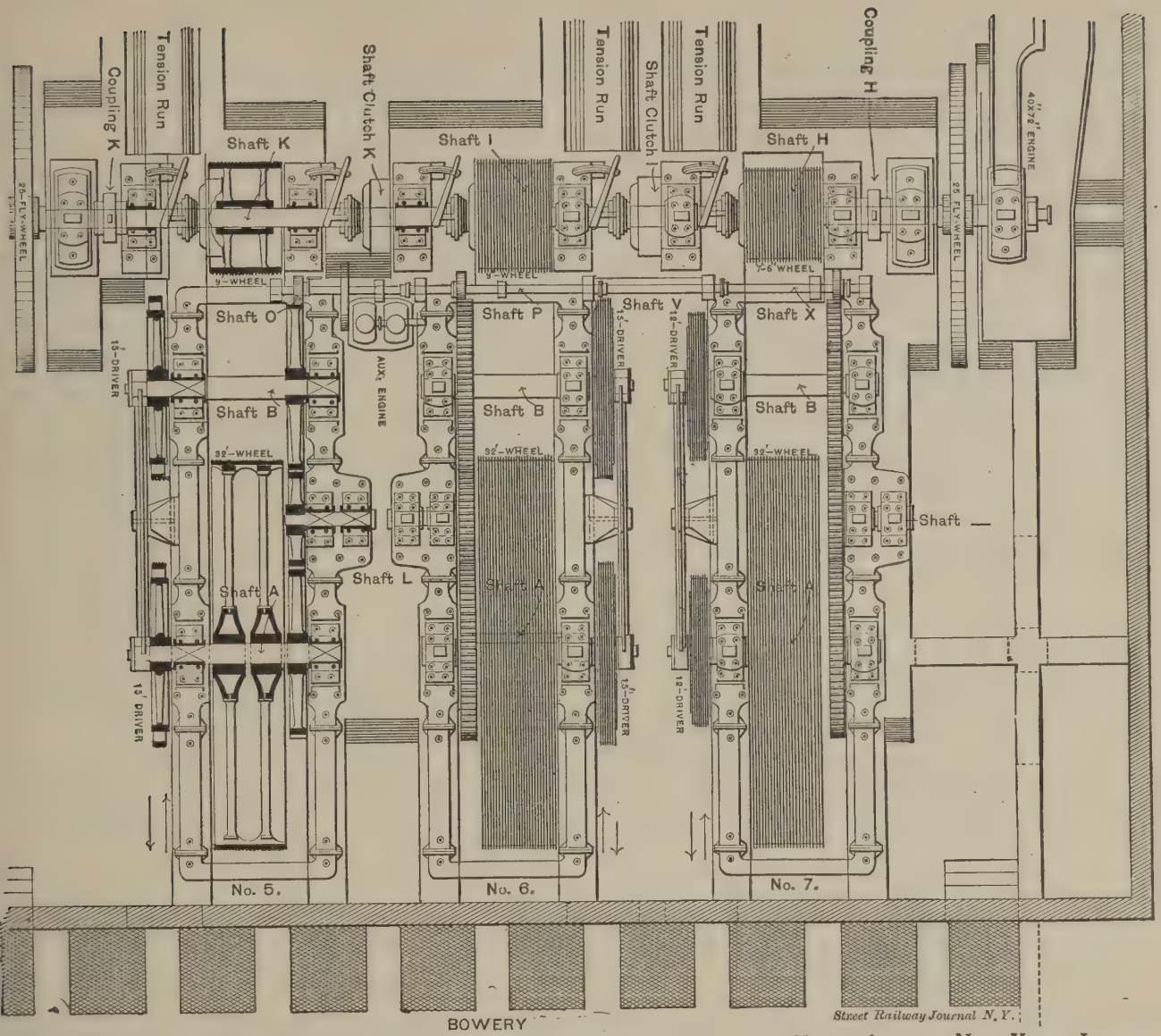


FIG. 262.—ROPE TRANSMISSION WITH INTERMEDIATE GEAR—BOWERY STATION, THIRD AVENUE, NEW YORK, LINE.

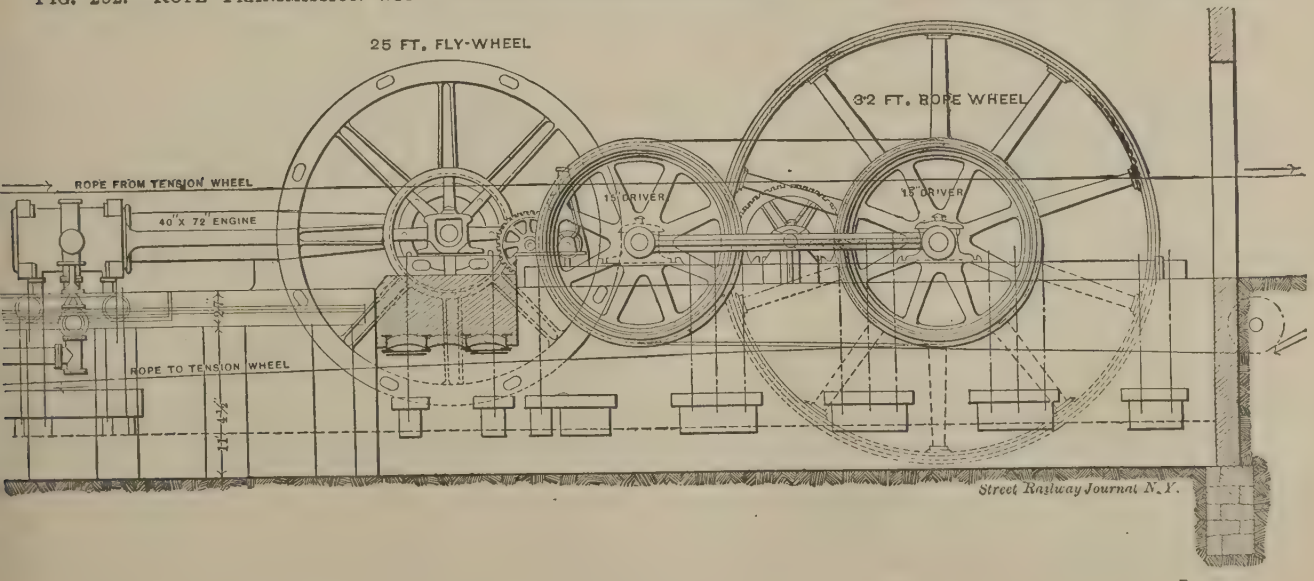


FIG. 262A.—ELEVATION OF ROPE AND CABLE SHEAVES—BOWERY STATION. THIRD AVENUE, NEW YORK, LINE.

drums and on the incoming line is directly increased by that on the outgoing line, the latter should be as small as will be efficient, in order to lessen wear and reduce friction. Hence, both drums should be driven when the work to be done approximates the hauling power of a single drum.

It must not be expected, however, that by driving both drums the total hauling power will be double that of one drum driven, for, in case solid drums are employed, the first drum, or the one that receives the incoming line, will do nearly eighty-seven per cent. of the work.

In order to show more effectually the advantage of driving both drums and using several wraps to diminish the tension on the ropes, the following formulæ and table are quoted from a reliable authority.

Let, in each drum of a pair (Fig. 269), the arc of contact of the cable with its grooves, be the same, and, with a radius of 1, equal a, the coefficient of groove friction be f, the tension on the incoming line of the cable be T, and the tensions on each outgoing line from its groove, in order, be t_1, t_2, t_3, etc.; also let the corresponding haul of each groove be h_1, h_2, h_3, etc.

Then for the 1st driving groove, $T = t_1 e^{af}$, and h_1

$$= \frac{T}{e^{af}}(e^{af} - 1),$$

for the 2d driving groove, $t_1 = t_2 e^{af}$, and h_2

$$= \frac{T}{e^{2af}}(e^{af} - 1);$$

for the 3d driving groove, $t_2 = t_3 e^{af}$, and h_2

$$= \frac{T}{e^{3af}}(e^{af} - 1);$$ and similarly for the remaining driving grooves. The total haul, $H = h_1 + h_2 + h_3 +$ etc., $= T(e^{af} - 1)\left(\frac{1}{e^{af}} + \frac{1}{e^{2af}} + \frac{1}{e^{3af}} + \text{etc.}\right)$;

a decreasing series never to equal T.

With one drum driven alone $H = h_1 + h_2 + h_3 + h_4$ (see Fig. 269) in which each drum has four grooves), the driving grooves being from 1 to 4 in numerical order.

With two drums driven the hauling power of the first drum will be $H_1 = h_1 + h_3 + h_5 + h_7$, and the hauling power of the second drum will be

$$H_6 = h_2 + h_4 + h_6 + h_8$$

That the total hauling power $H_1 + H_2$ shall equal on line H_2, or twice that of one drum driven alone, it will be seen $h_5 + h_6$, $+ h_7 + h_8$ must equal $h_1 + h_2$, $+ h_3$, $+ h_4$; only possible, as an inspection of the preliminary formulæ will show, when $T = t_1 = t_2 = t_3$ etc., or H, h_1, h_2, h_3, etc., each equals zero.

THE MAXIMUM HAULING POWER OF CABLE WINDING DRUMS.

Grooves.	Tension on each incoming line, in terms of its outgoing.	Maximum Hauling Power of each Groove, in order. In terms of the tension on first incoming line, or T.	Numerical Values: for $a = 180°$, $f = 0.15$, $T = 1$. One Drum driven only.	Both Drums Driven. First Drum.	Both Drums Driven. Second Drum.
1	$T = {}_1e^{af}$	$\frac{T}{e^{af}}(e^{af} - 1)$	0.3752	0.3752	.....
2	$t_1 = t_2 e^{af}$	$\frac{T}{e^{2af}}(e^{af} - 1)$	0.2346	.....	0.2346
3	$t_2 = t_3 e^{af}$	$\frac{T}{e^{3af}}(e^{af} - 1)$	0.1464	0.1464	.....
4	$t_3 = t_4 e^{af}$	$\frac{T}{e^{4af}}(e^{af} - 1)$	0.0914	.....	0.0914
5	$t_4 = t_5 e^{af}$	$\frac{T}{e^{5af}}(e^{af} - 1)$	.....	0.0572	.....
6	$t_5 = t_6 e^{af}$	$\frac{T}{e^{6af}}(e^{af} - 1)$	.....	.....	0.0357
7	$t_6 = t_7 e^{af}$	$\frac{T}{e^{7af}}(e^{af} - 1)$	.....	0.0222	.....
8	$t_7 = t_8 e^{af}$	$\frac{T}{e^{8af}}(e^{af} - 1)$	.....	.....	0.0139
9	$t_8 = t_9 e^{af}$	$\frac{T}{e^{9af}}(e^{af} - 1)$	.....	.....	.....
Hauling power of each drum.			0.8476	0.601	0.3756
Total hauling power.....			0.8476	0.9766	
Tension on last outgoing line.			0.1524	0.0234	

It is to be noted that where the arcs of contact of the cable with its grooves, in the case where two

drums are driven, are equal, H_1 is much greater than H_2, the first drum doing a large part of the total work.

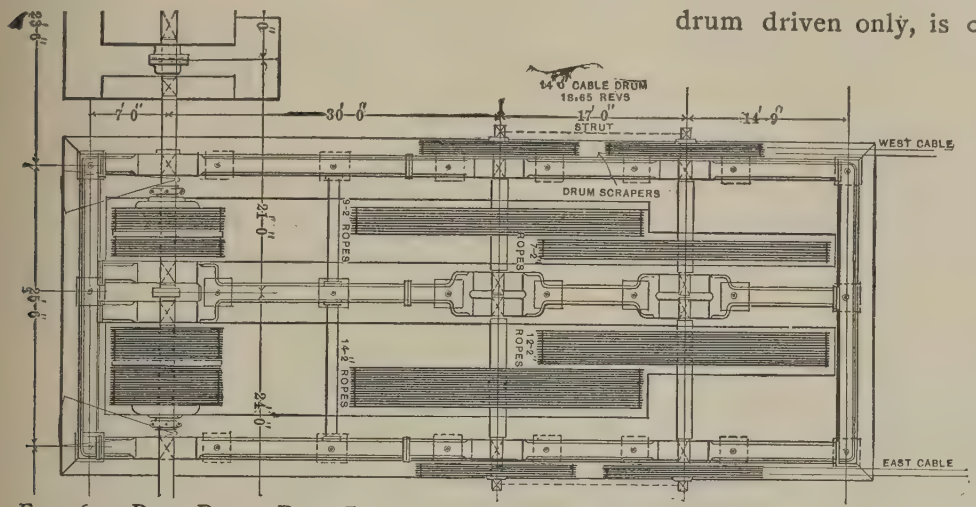


FIG. 263.—ROPE DRIVE, BOTH DRUMS DRIVEN—CABLE POWER STATION, PENNSYLVANIA AVENUE, WASHINGTON, D. C.

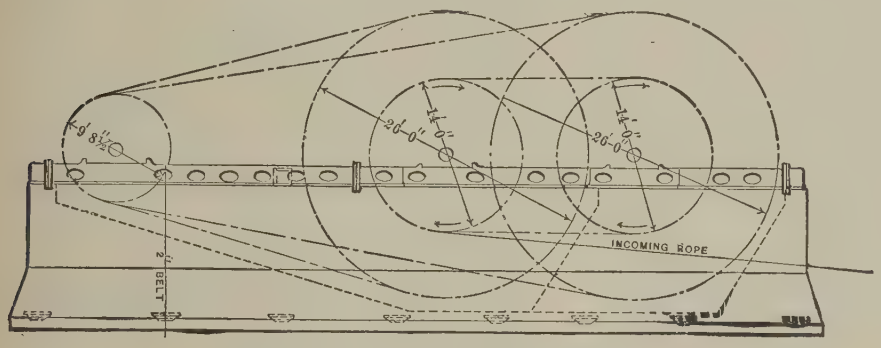


FIG. 263A.—SIDE ELEVATION OF SAME.

The accompanying table gives the numerical values of the hauling powers, in terms of T— (or for $T = 1$). From this it will be seen, with a single drum driven only, the total hauling power is 0.8476, or nearly eighty-seven per cent. of the total hauling power with the two drums driven.

The tension on the outgoing line, with a single drum driven only, is 0.1524, and, with the two drums driven it is 0.0234; these, for a total hauling power of 60,000 lbs., correspond to 9,144 and 1,404 lbs. respectively.

The following is given as an illustration of the method of computing the hauling power of drums, from the foregoing formulæ and table.

Referring to the first proposition: $T = t_1 e^{af}$, in which generally T is known or may be taken as the unit of comparison, and the value of t_1 is required. The equation transformed becomes then

$$t_1 = \frac{1}{e^{af}}$$

in which $e = 2.71828$: its logarithm is 0.4342945.

The arc of contact, 180° $a = \frac{2.\pi}{2} = \pi = 3.14159$: and the coefficient of friction f_1 may be taken at 0.15; hence $af = 3.14159 \times 0.15 = 0.47124$.

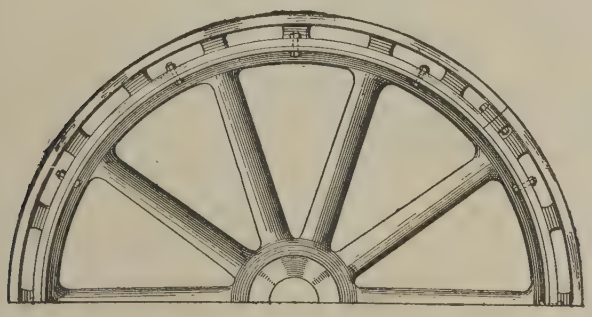


FIG. 265.—DRUM WITH REMOVABLE RIM.

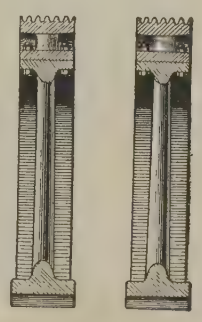


FIG. 264.—SECTIONS OF DRUMS WITH REMOVABLE RIMS.

Therefore $e^{af}=2.71828$ and log. $e^{af}=0.47124 \times$ log. $2.71828 = 0.47124 \times 0.4342945 = 0.2046548$. This is the logarithm of $1.602=e^{af}$:

$$\text{hence } t_1=\frac{1}{1.602}=0.6242.$$

and $h_1=T-t_1=1-0.6242=0.3758$:

By carrying out the decimals farther, the last decimal will agree with that given in the table.

To compute the next groove, substitute t_1 for T and t_2 for t_1, (as indicated in the second column), or find as before, the value of t_2 from formula in the third column.

In case drums are employed, having loose grooved rings in which the rope rests, the condition—it is claimed by those who advocate the use of this type of drum—are somewhat different and the approximate figures given in the illustration (Fig. 270) are based on the well known theory of sustaining a load over sheaves. The load in this

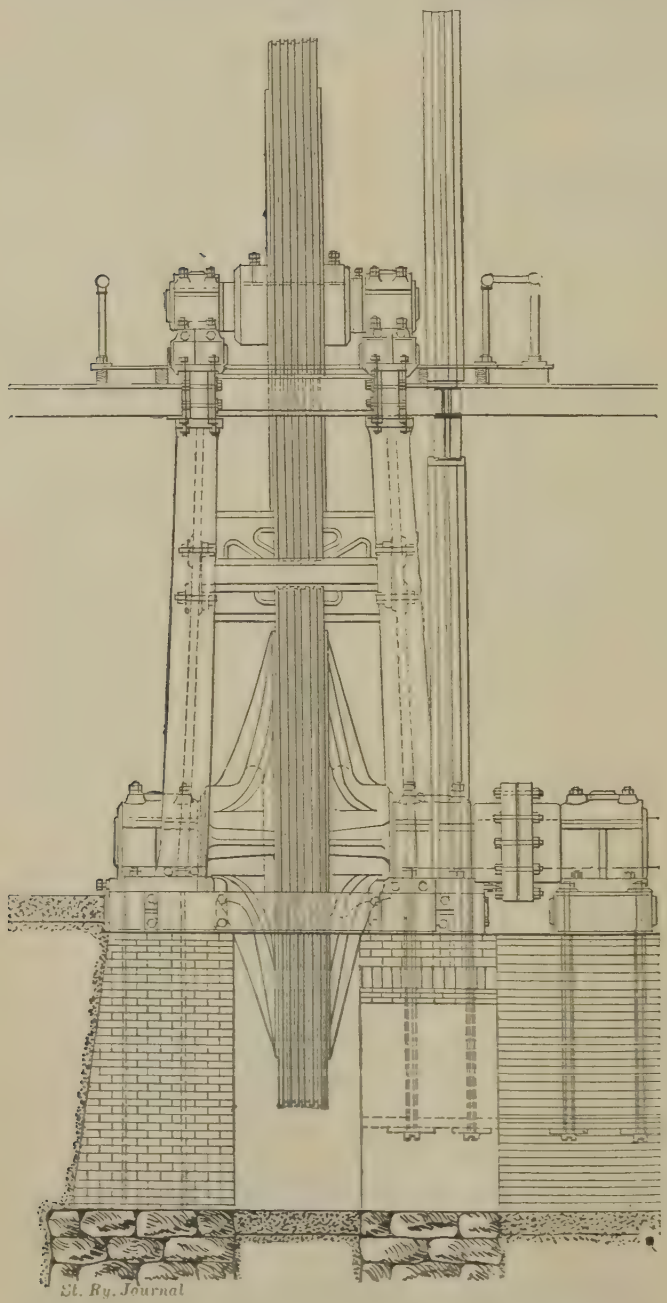


FIG. 266.—DRUMS IN VERTICAL POSITIONS—PHILADELPHIA TRACTION CO.

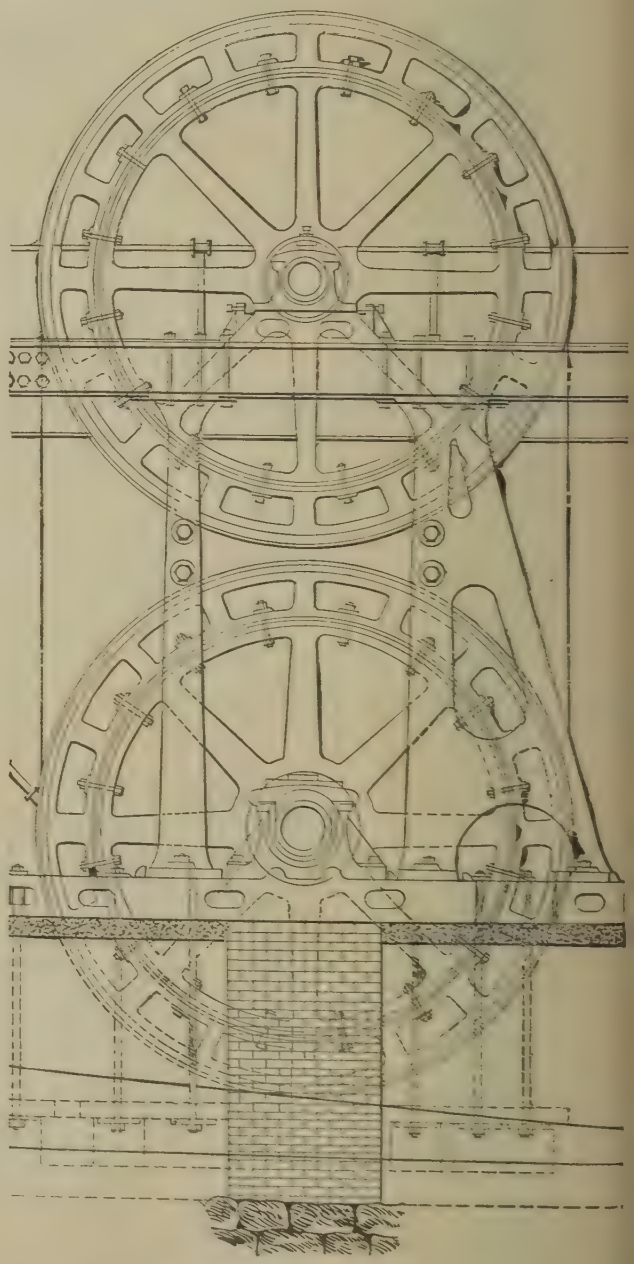


FIG. 267.—SIDE ELEVATION OF DRUMS.

case is presumed to be 60,000 lbs., and the load on the tension carriage 6,000 lbs., the reduction in pounds on each of the equalizing rings (not on solid grooves) will be as shown. Hence, we find that the aggregate of the leading drum is 105,000 lbs., and the aggregate of the second drum is

ated over grooved sheaves are extensively employed for this purpose. A proper form of groove is shown in Fig. 272. The lower loop of the rope is usually made the hauling side, and the number of ropes to be employed depends upon the horse power to be transmitted. Usually, each rope may be rated to

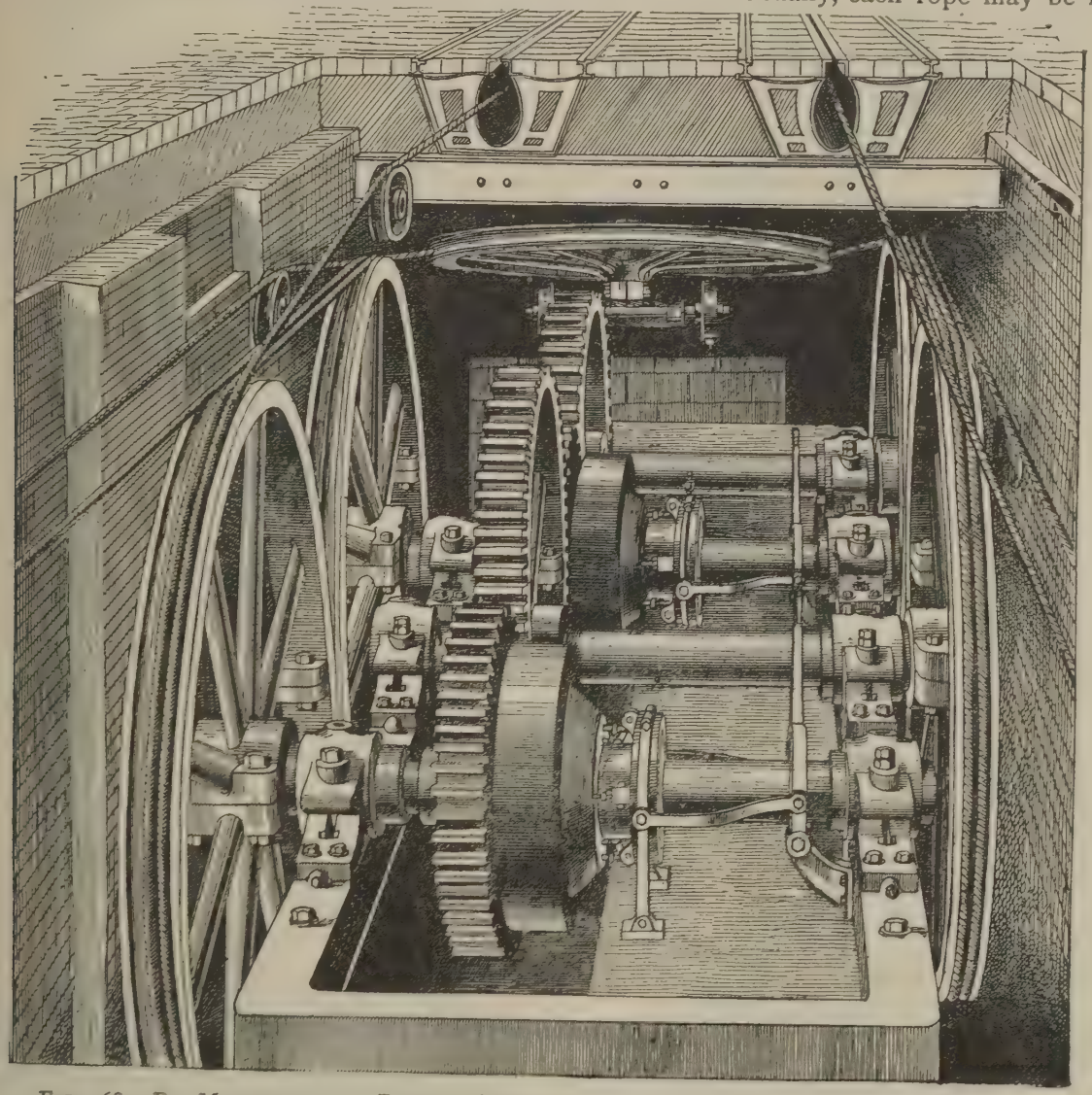


FIG. 268.—PIT MACHINERY FOR DRIVING AUXILIARY CABLE—CLEVELAND CITY CABLE RAILWAY.

8,000 lbs., or about one-fourth less than the work one by the leading drum.

COTTON ROPE OR BELT DRIVE.

Some advantages claimed for rope or belt transmission are: Absence of vibration and consequent noise; economy of space; small first cost; exact alignment of machinery unnecessary; economy of maintenance. Fibrous cotton ropes (Fig. 271) operhaul about 500 lbs. In service it is best to have the ropes as nearly one length as possible, and something may be gained by providing a weighted idle pulley for each separate rope to maintain a uniform initial tension. The rope, as usually constructed, is composed of fine cotton yarn laid with four strands around a central heart. Each of the four strands has a core of loose yarn, and around it are laid thirteen smaller strands which serve to strengthen

and protect the core from wear and from the atmosphere. The rope possesses the qualities of great strength, elasticity and durability. After being put in service the rope is treated to an anti-fraying compound which minimises the chafing and protects the surface from moisture.

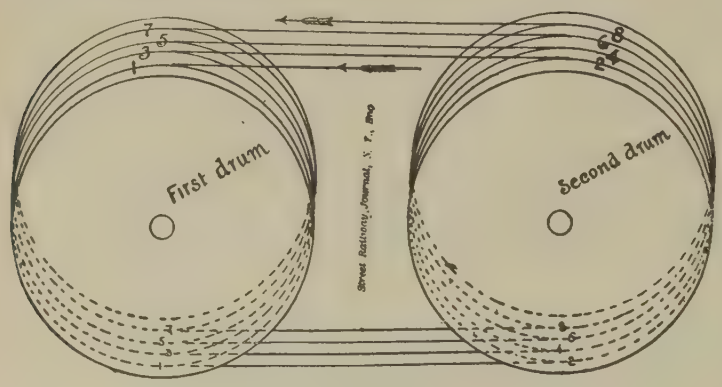


FIG. 269.

Unlay A four and a half feet, laying B^2 in its place. Unlay A^1 one and a half feet, laying in B^1. Cut all strands off to a length of about twenty inches. The rope now assumes the form shown in Fig. 274.

Each pair of strands is now subjected to the following treatment, which completes the splice: Unlay strand B^4 two and a half turns; unlay strand A^4 two and a half turns; split B^4 and A^4 in halves as far back as they are unlaid and "serve" one-half of each strand at the end with a small piece of twine. Served half of A^4 now laid in two and a half turns; served half of B^4 now laid in two and a half turns. Both half strands now meet, and are then tied in one single knot, making rope at that point original size.

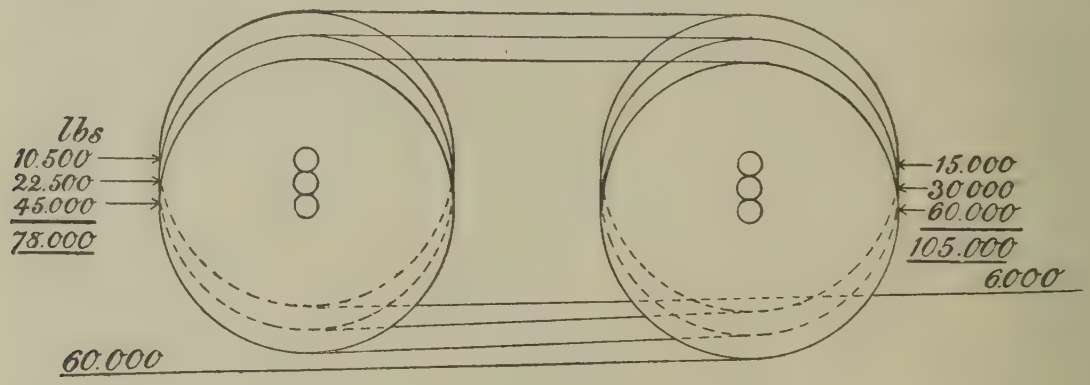


FIG. 270.

Cotton ropes are usually spliced by the English method, and, for one and three-quarters or two inch ropes the splice should be about twelve feet long. The following instructions will enable an intelligent mechanic to make this splice:

Tie a small piece of twine around the rope to be spliced, six feet from each end. Unlay strands back to each string.

Butt the rope ends and twist each corresponding pair of strands loosely, to keep them from becoming tangled, as shown in Fig. 273. c and c^1 are the small pieces of twine; c^1 is now cut off, B^4 unlaid, and A^4 carefully laid in its place for a distance of four and a half feet from junction. B^3 is next unlaid about one and a half feet and A^3 laid in its place. The ends of cores are now cut off so that they just meet.

Half strand A^4 is now raised with a marline spike, and half strand B^4 knotted in or worked around A^4 four turns, bringing it to half of A^4, which was not laid in. This half is now split as shown in Fig. 275, half B drawn through the opening thus made and tucked under two whole strands as shown. The ends of A and B are now cut off leaving them

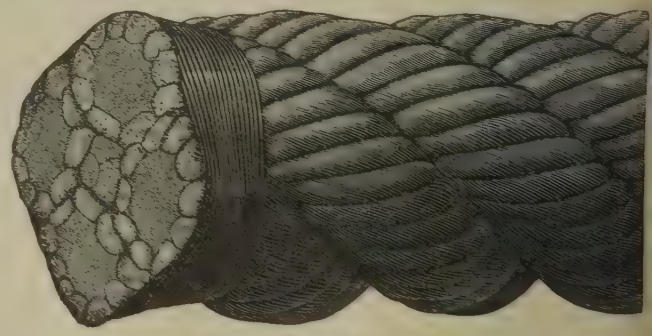


FIG. 271.—COTTON ROPE.

about four inches long. After a few days' wear they will draw into the body of the rope or wear off, so that the locality of the splice can scarcely be detected when at rest.

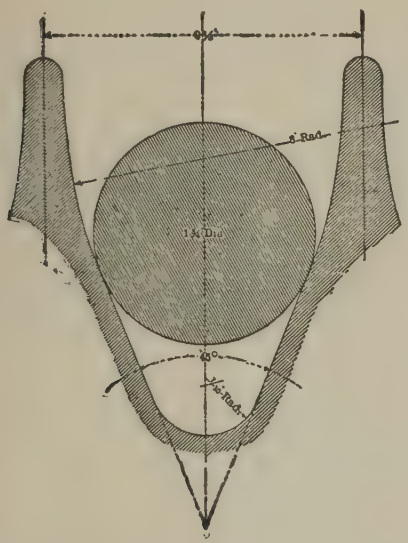


FIG. 272.—PROPER FORM OF GROOVE FOR COTTON ROPE.

Owing to the manner in which the half strands are locked in the above figure the strength of the rope is not appreciably impaired.

PIT PULLEYS.

We come now to consider the size and arrangement of the pit or deflection sheaves, which conduct the rope from the conduit to and from the power house. The winding drums are sometimes located in a pit under the track; but this position is not recommended, for, when so placed, they are

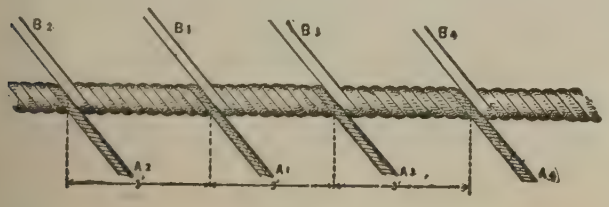


FIG. 274.

exposed to the dirt and water that come through the slot everhead.

In designing a pit in its relation to the power house, care should be taken to use as few deflection sheaves as possible, and these should be about of the same diameter as the winding drums, say, as ten is to twelve. The life of a rope depends largely upon the number of bends it is required to make and also whether the bends are in the same direction or not.

A good design for pit and pulleys for two ropes illustrated in Fig. 276. By this arrangement only

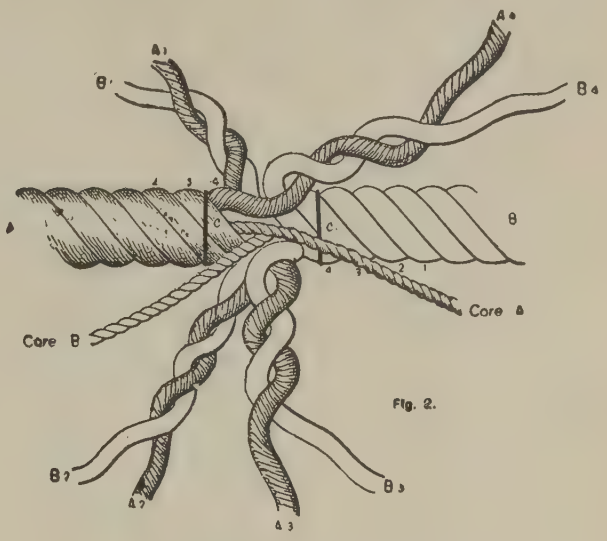


FIG. 273.—COTTON ROPE SPLICE.

two pulleys are required for each cable. These are mounted in nearly a horizontal position in the frames which are securely anchored to concrete foundations. Elevating sheaves, shown to the right and left in Fig. 277, conduct the ropes to their proper level in the conduit. These elevating sheaves should, usually, be equal in diameter to the pit sheaves, unless the angle of depression is a very slight one. It is a mistake to use too small a sheave

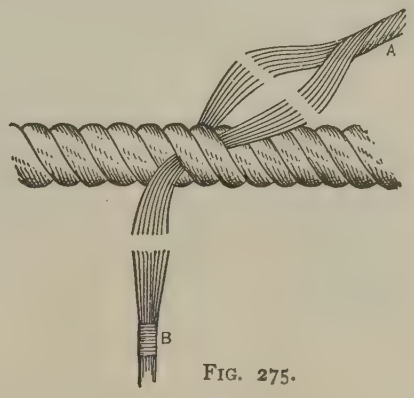


FIG. 275.

in this position, for a rope is injured almost as much by being required to conform to a short arc of a small sheave as though it encircled the entire circumference.

Another arrangement of pit sheaves for two ropes is shown in Fig. 278, where four sheaves are re-

quired for each rope, each pair being set at right angles to the other. Such an arrangement is sometimes necessary, but has a destructive effect upon the rope.

A very simple arrangement of pit sheaves for one rope is to mount the two sheaves in a horizontal position loose on the same shaft, at the side of the conduit, so that the rope is conducted to its proper level in the tube.

The pits being constructed under the streets, the roof must necessarily be supported in a very substantial manner, and this is usually done by means of iron girders, with brick arches between, upon which the pavement is placed (Fig. 279). Provision should be made for proper drainage, and when this is not possible, pumps must be provided for removing the water.

SIGNALS.

Signal appliances are very important in the operation of a cable line, and should in all cases be provided. Electric signals with proper instruments and a code are recommended. The wires may be laid within the conduit or in a pipe alongside the conduit between the tracks, with signal keys at certain manholes. A better arrangement, however, provided poles are allowed, is to support the wires

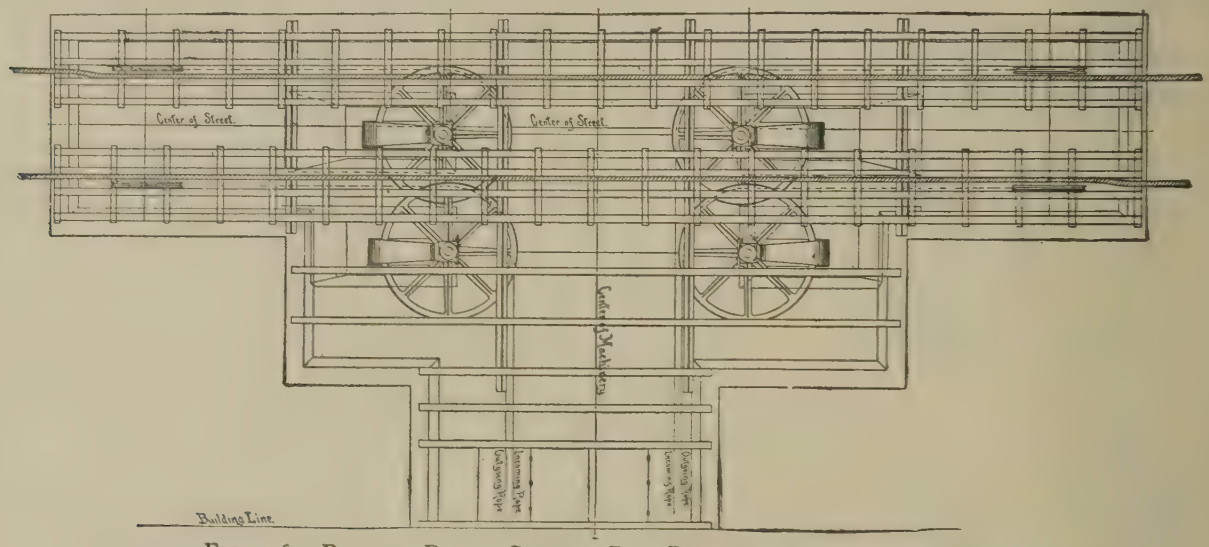


FIG. 276.—PLAN OF POWER STATION PIT—PEOPLE'S LINE, ST. LOUIS, MO.

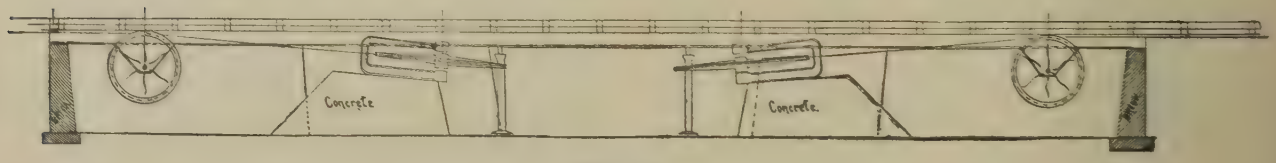


FIG. 277.

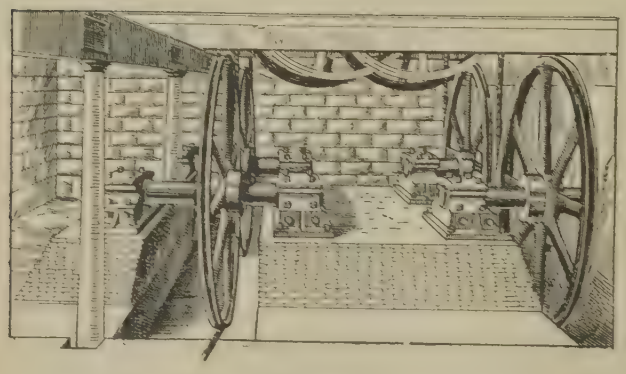


FIG. 278.

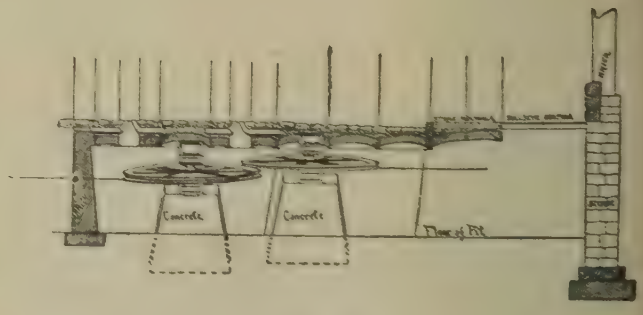


FIG. 279.

on poles along the street, with signal boxes at proper intervals. By means of the signals the engineer may be at once notified of an accident on any part of the line, and the wrecking wagons can be promptly sent out. In addition to the electric signal it is customary to provide an automatic device to detect any fault in the rope.

To provide against possible delay in case of accident or a blockade, all well managed roads are provided with wrecking wagons, which are kept ready for service by being supplied with all necessary tools and by having trained horses and a trained crew always ready to operate them at a moment's notice.

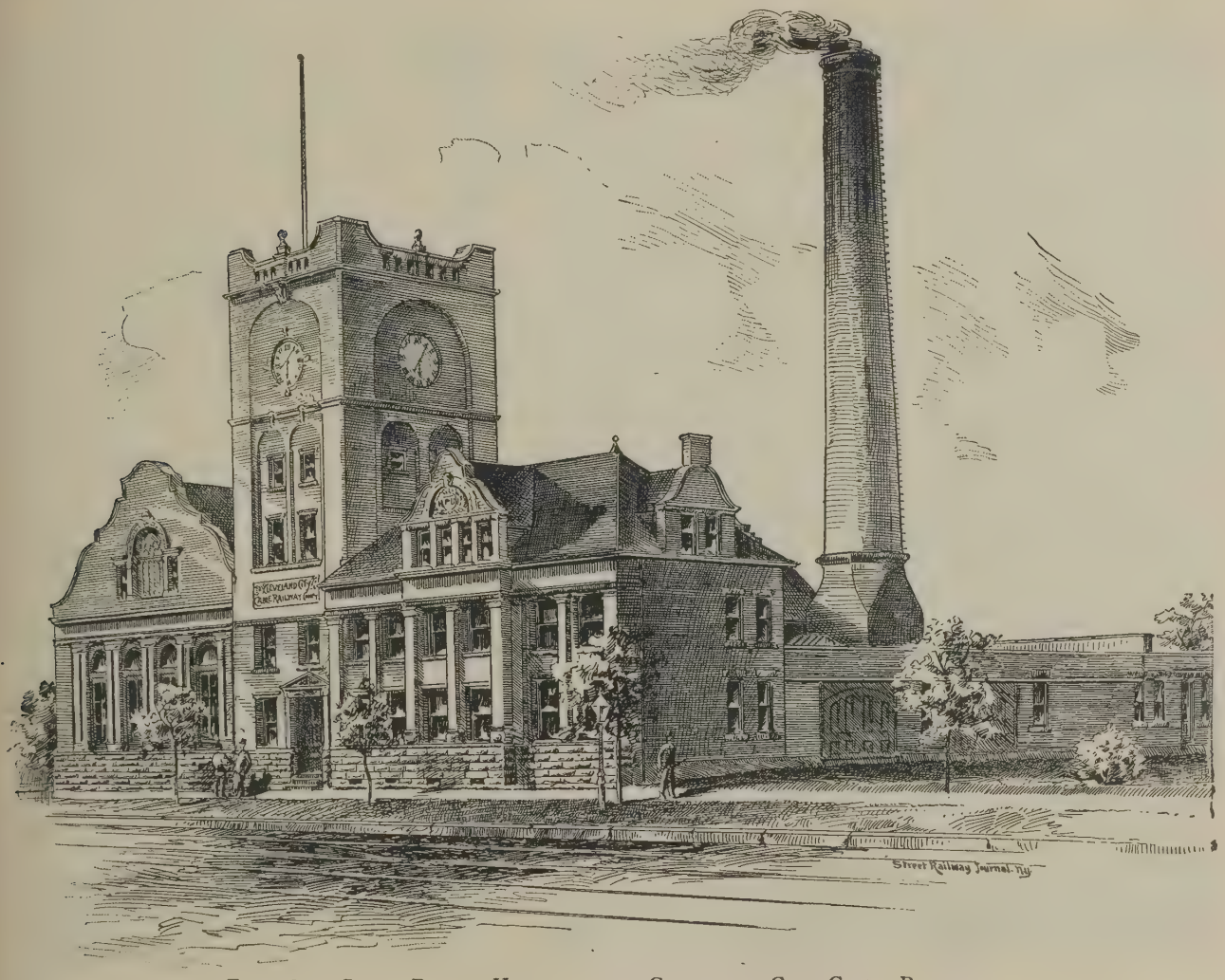


FIG. 280.—CABLE POWER HOUSE OF THE CLEVELAND CITY CABLE RAILWAY.

This is usually placed in the pit, and consists of a forked spring which closely embraces the rope, and rings a signal bell in case a broken strand or wire should come in contact with it.

In addition to the signals, a watchman is employed on some lines who is stationed in the pit or power house to watch the rope continually, in order to detect any signs of weakness or tendency to strand.

THE POWER HOUSE.

This should be a substantial building with ample room not only for the engines and machinery, but also for a repair shop, storage and suitable offices and waiting rooms, if required. It is desirable to have the engine room light and airy; and it is a good plan to provide a balcony leading off from the waiting room, from which visitors may watch the operation of the machinery.

No uniform plan for a power house can be given. The location and financial condition of the company usually govern the selection of material and plan of construction. The same remarks, however, which were made on page 60 with reference to electric power stations apply in the case of cable lines. Figs. 280 and 281 illustrate two interesting power stations that may well serve as models where a pleasing effect is desired.

FIG. 281.—POWER HOUSE—BALTIMORE TRACTION CO.

THE ENGINES AND BOILERS.

Any approved type of engines and boilers of sufficient capacity may answer the purpose of cable traction. The most desirable is one that will maintain a uniform speed whatever the variation of load. The high pressure, automatic cut-off, horizontal engines have, heretofore, been most generally employed; now, however, a number of compounds are employed in cable service, and their use is recommended in localities where water can be had in sufficient quantities for condensing. With any type of engine it is usual to employ a heavier flywheel than is required for ordinary work, especially on lines with heavy grades where the load fluctuates widely.

The engine and boiler equipment should be in duplicate, to provide against possible delays from accident to the machinery, and also to give time for rest and for making necessary repairs. The engines employed are generally from 200 to 1,500 H. P., depending upon the character of the line and the amount of traffic. In emergencies like the advent of a snow storm or excessive traffic, both engines can be put in service. The amount of horse

power to be provided per car cannot be definitely stated. This will depend upon the length of the line and the number of cars operated. The average, however, computed from the actual horse power provided on a dozen lines in successful operation in this country is twenty-five H. P. per car, including reserve. The average horse power per car provided on the cable lines of Melbourne, Aust., which aggregate ninety-one miles, is fifteen for the average number of cars run. The average horse power to move 1,000 ft. of cable on home lines is 1.6. The power required to move the cable alone varies from thirty-five to seventy-five per cent. The average for a dozen roads in operation is fifty-four per cent., this depending largely, as before stated, on the relative diameters of the carrying pulleys to the diameters of the journals.

In order to determine the approximate amount of steam horse power that should be provided to operate a line employing less than ten miles of rope the following plan is suggested: Allow four horse power to each 1,000 ft. of rope, reckoning each right angle curve equal to 1,500 ft. of straight track. Add three horse power for each car, if of ordinary size, and sixty horse power for engines and machinery.

MODIFIED CABLE SYSTEMS.

So far we have confined our description to the standard cable systems which use a vise or roller grip for transmitting power to the car. Other systems, however, have been devised and deserve a brief description. One of these, known as the "Ladder Cable System," was operated for some time in the city of Brooklyn, N. Y., but afterwards abandoned. The distinctive feature of this system was in the construction of the cable and in the car connection. The hauling cable was made of two wire ropes, each about three-fourths of an inch in diameter, and composed of six large wires one-fourth of an inch in diameter without a hemp core. These ropes were placed side by side, about an inch apart, and connected together every six or eight inches by steel or bronze clips, forming a ladder. This cable was mounted to run on split pulleys in a shallow conduit directly under the slot.

Underneath the car a sprocket wheel was hung, having suitable teeth, which, when lowered through the slot, engaged with the clips of the cable, and caused the wheel to revolve. To start the car a band brake was applied to the sprocket wheel, which checked its motion and caused the car to move with the cable. At the terminals and cable crossings the sprocket wheel could be readily lifted from the slot. The cable was driven in the ordinary manner, by solid drums having grooves or channels wide enough to receive the flat side of the cable.

Another system, known as the "Chain Pump Cable" was constructed on an extensive scale in the city of Newark, N. J., but was never put into service. This system employed a wire rope of ordinary size, having a wire core. Attached to this rope, every six or eight inches were metal collars or buttons, about three inches in diameter, securely held in place by being pressed on in halves and the parts riveted together and babbited. This rope thus equipped was mounted in a shallow conduit close to the slot, and was carried upon small two wheel trucks, about ten feet apart, to the axle of which it was securely attached, so that the trucks travelled with the cable, small tracks for the wheels being provided in the bottom of the conduit. The truck wheels were about six inches in diameter, mounted loose on six inch axles. The rope was made to travel slightly to one side of the slot, bringing the side of the button directly under the opening. Power was transmitted to the car by means of a sprocket wheel hung under the car, the arms of which engaged with the buttons through the slot. The car was started by means of a band brake, in about the same manner as described for the ladder cable system. In place of the sprocket wheel a revolving metal belt was afterward substituted. This belt was provided with arms which were designed to engage with the axles of the travelling trucks, the object being to dispense with the buttons and depend only upon the trucks to impart motion to the car. In this system the cable was driven by means of a single horizontal pulley, having chambers or pockets in the face of the rim of sufficient

depth to receive the buttons and trucks. Around this driving pulley the cable made but one wrap, being driven by the contact of the buttons against the shoulder of the chamber. The proper tension was maintained by means of a tension carriage placed in a vault at the end of the line, the pulley of which was provided with chambers the same as the driving sheave, and was also mounted upon its car in a horizontal position. The curve pulleys were also provided with pockets. An attempt was also made during this experiment to avoid the use of curve pulleys, by placing the tracks in the conduit in a perpendicular position on the side of the conduit, with spiral approaches, so that the trucks would lead the rope around the curve.

The third modification, known as the "Twin Cable System," was tried on a short experimental line in the city of Binghamton, N. Y., and was operated successfully for about two years, the grades on the line being over twelve per cent. By this method two cables are operated side by side, one being a rope of ordinary size, and the other a small rope only one-half inch or less in diameter. The large rope was driven in the ordinary manner, and the small or secondary rope received its motion and power by means of its frictional contact with the same curve and carrying pulleys upon which the main cable travelled. The terminals of the line were necessarily constructed with a loop. Power was transmitted to the car by means of the small rope which was led up through the slot over a loose pulley mounted under the car. Two thin guide pulleys were provided which revolved with one edge through the slot and so protected the cable from chafing against the side of the slot, and also conducted it back to its place in the conduit. The car was started and stopped by means of a band brake on the middle pulley, thus avoiding the wear due to the grip in the ordinary systems. Only a shallow conduit was required.

This system has been further improved by introducing a train of differential gear with friction clutches between the cable pulley and the car axles, by means of which the car can be run twice as fast as the cable, or be run at half speed in the opposite direction. In practice the car is designed to have varying speeds in both directions. It is run at cable speed or double speed, and half speed backwards, at the will of the driver.

COST OF CABLE ROAD CONSTRUCTION.

What will it cost, is the first and most important question to settle before engaging in a cable enterprise, but in order to make a close and accurate estimate of the cost of any particular line all the conditions must be known. These conditions include the character of the surface formation, whether it be of sand, clay or rock; the depth of the substructures already in the street, including the water pipes, gas pipes and sewers; the width of the street and the amount of vehicular traffic thereon which will interfere with the work to a greater or less degree; the extent of the temporary tracks necessary to prevent the interruption of existing traffic; local regulations regarding the storing of material; the climate, whether mild all the year or subject to periods of very low temperature, requiring heavier construction to prevent slot closure; the price of material and labor; the character of the route, whether level or hilly, straight or crooked, and whether bridges, viaducts and crossings for steam lines are required; the amount of anticipated traffic; the ability of the engineer employed, and the sums, if any, that must be paid for city inspectors or for political "heelers." Under ordinary conditions one mile of double track, straight street construction, including the rope, will cost about $100,000. Some lines having a shallow conduit formed with planks have been built for about $75,000 per mile, and a few have cost nearly $200,000.

The actual entire cost of a certain line with deep conduit including 2.95 miles of double track, was $694,329, and this amount was divided as follows:

Street work, complete	$372,372
Real estate, building, machinery and rope	240,305
Rolling stock	81,652
Total	$694,329

The construction on this line was first class in every particular, and included considerable special

work, consisting of one ninety degree curve, two crossings for steam lines, crossings for a number of street car lines and a large amount expended in moving gas and water pipes and a crossover grip switch at each terminal. The power house and car barn were of large dimensions, and the rolling stock included eighty-three grip cars, coaches and summer cars.

These figures have sometimes been exceeded in cable construction, but rarely need be, except under the unfavorable conditions which exist in the larger cities of the country.

The actual cost of another road of 1.84 miles of double track, closely resembling the one described above in all the details of street construction, and not inferior to it, except in buildings and rolling stock, and one which required only a small outlay for moving gas and water pipes, was as follows:

Street work complete	$202,692
Real estate, buildings and machinery	93,353
Rolling stock	17,324
Total	$313,369

This is equivalent to a total investment of $170,310 per mile of double track, including everything except expenses involved in securing franchise and negotiating bonds.

The following estimate is given as the average of the actual cost of a half dozen lines that have been built in different parts of the country:

POWER HOUSE AND PLANT.

Real estate	$10,000
House 175 × 100 ft.	25,000
Two engines and foundations	19,500
Driving machinery for two cables with the foundations	23,000
Boilers and settings	14,000
Brick smokestack 100 ft. high, 5 ft. in diameter	5,000
Tension cars and tracks	2,500
Heaters, pumps, fittings and sundries	3,000
	$102,000

Though the cost of power, car houses and plant does not vary directly as the length of the line, the following figures will serve as a basis of calculation within reasonable limits:

APPROXIMATE COST OF BUILDINGS AND MACHINERY PER MILE OF CABLE ROAD.

(DOUBLE TRACK.)

Ground for power and car house	$10,000
Building	15,000
Engines and boilers	10,000
Driving machinery	10,000
Total	$45,000

GENERAL STREET CONSTRUCTION.

THREE MILES DOUBLE TRACK.

19,800 cu. yds. trench excavation at 75 cents	$14,850
7,920 cast iron yokes, 350 lbs. each, 2 755,000 lbs at 1½ cents	41,580
880 carrying sheaves, complete, at $3.75	3,300
21,120 yds., 50 lbs. per yard steel slot rails, 1,056,000 lbs. at 2½ cents	26,400
21,120 yds., 60 lbs. per yard steel track rails, 1,185,000 lbs. at 2¼ cents	28,512
154,000 lbs. cast iron manhole covers and frames complete at 1¾ cents	2,695
10,000 cu. yds. Portland cement concrete at $8.50	85,000
15,840 ft. of double track laying at $1	15,840
22,200 sq. yds. granite block paving at $3	66,600
Sewer connections	9,000
32,180 lineal feet of steel wire cable wire at 33 cents	10,619
	$304,396

SPECIAL STREET CONSTRUCTION.

Some details may be estimated as follows:

Main vault at engine house and fixtures	$8,000
Two end vaults with fixtures	5,000
Special street sheaves for summits of grades, etc.	1,500
Two grip switches	2,500
Two coach switches	1,000
One crossing	1,500
180 degs. of double tracked curve	9,000
	$28,500

Of these items the first three or four are required on any line without regard to length.

ROLLING STOCK FOR THREE MILES OF ROAD.

TRAINS RUNNING ON FOUR MINUTES HEADWAY.

15 grip cars and grip at $1,000	$15,000
15 coaches at $1,200	18,000
	$33,000

Or there may be used 15 combination cars at $2,200.

the most desirable animals command too high a price, but good qualities should be insisted upon without regard to price. The most careful buyer will sometimes make mistakes or, rather, an animal that has some good points will often go to pieces quickly, but mistakes will grow less and less as one gains in experience. When it is possible horses should be bought on condition of ten days' trial.

New horses on being introduced to the stable should be assigned to a clean, airy department specially set apart for this purpose and never used for other purposes. They should be allowed a day or two for rest, especially if they have been transported any distance. Then, if they take their feed well, they may be put to quarter or half work with a steady mate, under a careful driver who will take pains to break them in to their work, and all the time they should be carefully watched.

Almost invariably the new horses will have a short season of sickness, "becoming acclimated," as it is termed, soon after being introduced to the new work, but a change of feed and some of the simple remedies will soon bring them out all right. After about two months they will usually become accustomed to the noise and sights of the streets and may be put to full work, and the superintendent should personally see that they are properly mated, and assigned to the care of a suitable hostler, according to the disposition of the horse and the man, much depending upon the adaptation of each to the other.

The horses should give indications of merit from the start; usually a street car stable is not a horse training establishment.

After about one year the new animals will become "seasoned" and may then be considered good for the average life of the stable.

This much in a general way regarding selection. The particular practice on some lines in large cities is about as follows:

The purchases are usually made at the horse market from regular dealers who import Western stock. All animals are taken upon five to ten days' trial. When introduced into the stable they are put into the reception department, a section apart from the other portions of the stable. A careful description covering age, weight, color, etc., of each horse is taken by the superintendent in conjunction with the stable foreman, and a return made of the reception to the office.

A physical examination of each animal is then made by the veterinary surgeon, and a separate report of its result is filed. Special feed is given, with rest and any necessary tonics or medicines for a day or two, with, perhaps, an hour's exercise in the drill room connected with the stable. The trial trip is then made, and the character and disposition of the animal, under the conditions of his work, tested. When fresh from work, warm and excited, he is again examined by the superintendent and the veterinary and the result noted. After remaining quiet for a day, that any latent stiffness or lameness which actual work may develop may be noted, he is again tested by being put to longer and harder work, specially to try his wind and general strength. These trials and subsequent examinations are continued until the limit of the time given is exhausted, and then, as the result of a final examination by the superintendent, the president or vice president being present, the former makes a written recommendation to the president for the acceptance of certain animals of the lot and the return of the rest to the seller. Upon the approval of this recommendation, the accountant makes proper entry of description, and an order is issued in written form for the numbering of the accepted horses.

FEED.

The feed of street car horses should always be prepared with great care. It is impossible to give the kind and exact amount of feed that would be suitable for all localities. The prices and supply must, in many cases, decide the practice. It is generally admitted, however, that ten or twelve pounds of cut hay mixed with fourteen pounds of oats and corn, ground half and half in bulk, is the most universal and, in the long run, the most economical daily ration for horses in street railway service, and that they should be fed three times a day at least. In some stables the corn and oats are ground separ-

ately and then mixed; it is claimed that neither grain is properly ground when mixed together. In warm climates where mules are employed good practice favors a ration consisting of from twenty-six to twenty-eight pounds of long hay and grain (corn and oats unground), half and half in summer, but nearly all corn in winter. The objections urged against cut food in warm climates are that it is liable to sour, attracts flies and frequently produces cases of colic.

It is a good practice to vary the feed, especially the proportion of corn and oats fed to the animals; it breaks up the monotony of always having the same ration, and stimulates the appetite. Corn, being more nutritious than oats, is usually fed in a larger proportion in winter; some feed as high as four-fifths of corn to one-fifth of oats in cold weather.

The following amounts and kinds of feed are quoted from the actual practice of stables in different parts of the country. The figures 1, 2, etc., indicate different roads in the same city.

CHICAGO. 1.—Fourteen pounds of corn and oats ground and seven pounds of cut hay; corn and oats mixed in proportion of bushel for bushel in cold weather and pound for pound in warm weather. Hay wet down and sprinkled with salt; seven pounds per feed, varied in case a horse is a heavy or light feeder. Hours for feeding, 2 A. M., 9 A. M. and 2 P. M.; about two and a half hours required for feedmen to finish. Average daily mileage, sixteen.

2.—Summer feed: Ten pounds of corn, five pounds of oats, three-fourths of a pound of bran, eight pounds of hay. Winter feed: Twelve pounds corn, three pounds oats, hay same. Part of the hay cut and mixed, part fed long. Upland prairie hay. Horses fed three times a day, hours to correspond with the hours of service. Daily mileage, eighteen to twenty; stable mileage, thirteen and a half to fourteen.

NEW YORK. 1.—Eighteen pounds of meal, seven pounds of cut hay, timothy and clover, one-third being clover. In mixing a small quantity of wheat bran and about three ounces of salt for each animal are added. The proportions of corn and oats by measure are one-fourth corn and three-fourths oats in summer. In very cold weather the quantities are half and half; in mild weather one-third corn and two-thirds oats. Hours of feed are 5 and 10 A. M. and 4 P. M., equal quantities each time. Hospital and half work ration: Long hay and boiled crushed oats. Road mileage, fifteen; stable mileage, twelve.

2.—Seventeen and a half pounds of meal in proportions of eleven pounds of corn and six and a half of oats ground together, ten pounds of cut hay, all thoroughly mixed and a little fine salt added.

Morning ration, given at 6 A. M., consists of five pounds of meal and two and a half pounds of hay. Noon ration, given at 10 A. M., same; evening ration, given at 4 P. M., seven and a half pounds of meal and five pounds of hay. In summer, noon feed consists of six quarts of dry oats in lieu of the cut feed. Mileage, sixteen and eighteen. In summer, the work is divided into two stages. In cool weather all the work is done without change. A little water is given as soon as the animal comes in from work.

3.—For large horses driven single, sixteen pounds of corn and oats in the proportion of one to four in bulk. Twelve pounds of cut hay. Hours for feeding, 4 and 9 A. M. and 4 P. M.

BROOKLYN, N. Y. 1.—In summer, fifteen pounds of grain ground in proportion by weight of one-third corn and two-thirds oats. In winter the weights are reversed. Fifteen pounds of cut hay moistened and mixed properly with the meal. About four pounds of cattle salt to each 100 horses. Hours for feeding, 5:30 and 10 A. M. and 4 P. M. Quantities at each feed, ten, eight and twelve pounds. Road mileage, sixteen.

2.—Twenty-eight pounds per day, composed of twelve pounds of corn meal, six pounds of oats, ten pounds of hay. A part of the oats fed dry at noon. A little less grain in summer than in winter. Mileage, fifteen and a half. Average working life, reckoned for a period of twenty years, seven years.

PHILADELPHIA.—Sixteen pounds of crushed corn per day from May 1 to October, and eighteen

pounds from October 1 to May, eight pounds of clover and timothy hay is cut and mixed with the crushed corn, and six pounds of timothy hay is fed long. In February and March, six or eight ears of corn are fed three times a week. In July and August, if the weather is very warm, oats are given in lieu of the crushed corn. Occasionally bran is mixed in the mess when the cut hay has not sufficient clover in it. Carrots are fed to off-feed horses in the fall and early winter. Road mileage, twenty-two.

WASHINGTON, D. C.—Morning feed, five pounds of cornmeal, five pounds of hay, one pound of bran. Noon feed, six quarts of dry oats. Evening feed, five pounds of corn meal, six pounds of hay, one pound of bran. The hay is cut, moistened and thoroughly mixed, a small quantity of salt being added.

BALTIMORE.—Fourteen pounds of corn chop, three pounds of mill feed, nine pounds of cut hay, thoroughly mixed and dampened, a little salt being added, and seven pounds of long hay. Hours of feed, three, regulated by the service. Mileage, eighteen to twenty.

PROVIDENCE, R. I.—Horses are fed from 4.30 to 5.30 A. M., 10 to 11.30 A. M. and 3.30 to 5 P. M., one man having charge of the feeding. The morning feed consists of three pounds of oats, one and three-quarters pounds corn (whole) and three pounds of cut hay; noon and evening three pounds of cut hay and eight and four-tenths pounds of ground corn and oats, two-thirds corn and one-third oats mixed together. The straw used for bedding is about thirty-five pounds per horse per month. Feed the same winter and summer. Horses are divided into groups of sixteen, each under the care of one man who takes care of and hitches up the horses at the proper time. Mileage, from twelve to fifteen, according to routes.

DETROIT, MICH.—Four pounds of oats at 4 A. M.; three pounds of oats, corn and cut hay, mixed, at 8 A. M., a little bran and salt being added; four pounds dry oats at 1 P. M.; at 5 P. M. cut feed, the same as at 8 A. M.; loose hay at 10 P. M. Total weight of hay, ten pounds per day. Summer and winter feed same. Mileage, thirteen or fourteen.

MILWAUKEE.—The daily ration for each horse consists of six pounds of cornmeal, four pounds of oatmeal, one pound of bran, four pounds cut timothy hay mixed, eleven pounds upland prairie hay loose, and seven pounds dry oats; total, thirty-three pounds. Hours of feed, 4 and 11 A. M. and 5 P. M. Mileage, twenty-four, changed every trip.

NEW ORLEANS, LA. 1.—Mules only being employed. Fourteen pounds of oats, fourteen pounds of timothy hay per animal, daily, from October to May, and twelve pounds of each for the remainder of the year. Hours of feed, 4 and 10 A. M., 2 and 6 P. M. Hay fed in racks in yard or cooling shed. Each hostler cares for twelve animals, to feed, water, clean and hitch up. No bedding is used. Animals turned out into the shed lots in pleasant weather. Mileage eighteen. No deaths from colic since corn was discarded.

2.—Twelve pounds of oats, two pounds of crushed corn, mixed and fed dry, eleven pounds of long hay in summer. Winter feed, eleven pounds of oats, three pounds of crushed corn, eleven pounds of long hay; total, twenty-five pounds. Hours of feed, with grain 3 : 30 and 9 : 30 A. M., a little bran being given once a week and a lump of rock salt kept in each manger. Hay is fed in equal parts at 7 : 30 A. M. and 5 : 30 P. M. Mileage, twenty in winter, eighteen in summer. Track level.

OAKLAND, CAL.—At 5 A. M., four quarts of rolled barley, dry; at 11 A. M. two quarts of rolled barley, dry; at four P. M., four quarts of rolled barley, every other day, alternating with six quarts of cut mixed feed in the following proportions: One pound of bran, three pounds of cut wheat hay, three pounds of cut oat hay, six pounds of ground barley. About twelve pounds of hay per horse per day are fed at eight o'clock in the evening.

In summer more cut feed and less barley is fed, and in winter *vice versa*. Each horse is fed, in addition, two handfuls of linseed meal once a month. Horses are watered before feeding, and are driven sixteen to twenty miles per day all at one time; groomed once a day, in the morning.

A good hospital ration consists of bran mash, sometimes with dry oats.

A handful of long hay thrown on the floor before the horses as soon as they come in from a trip is recommended.

Great care should be exercised in selecting the hay. It should always be the best to be had in the market. Neither musty hay nor musty straw for bedding should ever be used, as it tends to produce skin disease and other ailments in the stock.

The mixing box for feed may be of wood, but ers. In case the feed is mixed on the top floor of a stable it may be carried to the lower floors by means of iron flues or chutes, where the stablemen distribute it by means of two wheeled carts and measures.

The carts, chutes and boxes should always be thoroughly scraped, washed and salted after being used.

A little salt should be mixed with the feed, and loose salt fed three times a week. Horses need salt as much as men, and they would not eat it if it were not necessary for them.

FIG. 282.—CROSS GANGWAY, SHOWING WATERING TROUGH AND FILTER.

boiler iron is preferable. The box should be about three feet deep, ten feet wide, and. for large stables, from forty to fifty feet long. Boxes made T shape are recommended for large stables, as they give opportunity for three men to assist in the mixing. The hay is first put in then the grain, in a uniform layer, on top. Beginning at one end, or at the angle of T boxes, it is thrown over that with a fork and moistened with water from a hose located in a convenient position.

Some stablemen prefer a deep box in which the hay and grain can be put in in several alternate lay-

A reliable feeder is one of the first necessities of a well regulated stable. He should know how much each horse requires and gauge his measure accordingly. A horse should have all he can possibly eat, but nothing should ever be left over.

Metal feed boxes for the stalls are recommended, and if these can be had in the form of enameled kettles, holding about twenty gallons, all the better. These are not liable to become sour or foul, and can be readily cleaned with a sponge after using. They should be of sufficient depth to prevent the horse from nosing out his feed. No hay

racks are required. Long hay can be fed from the floor.

Water should be given frequently. For convenience, watering troughs should be provided along every cross gangway, and should be covered with lids that will close themselves.

A few stables are provided with troughs of running water along the head of each stall, two rows of stalls being made to face each other for this purpose. The troughs are covered, but have a round opening with a movable lid in front of each animal, so that the animals have access to water at all times. It is claimed for this practice that the animals having frequent access to water are not likely to gorge themselves after coming in from a trip, and that no evil effects follow this practice. The water is maintained at a uniform height in the troughs, without danger of overflow, by means of a stand pipe connected with a feed pipe running along the floor, which in turn is fed from a reservoir on the same level with the troughs, which being supplied by a float valve shuts off the street main and maintains the water always at the same level.

In warm weather, when the horse comes in from a trip, his head, nostrils and mouth should be thoroughly sponged, and then, after standing about an hour, a little water may be given, and after a short time more, all that the horse wants. It will be found that a horse will not drink nearly as much water if regulated as above, as he will if given access to the rough on coming in. On long lines in hot weather water should be given *en route*. The practice of mixing a little oatmeal with the water given at way stations, in summer, is recommended. It renders the water more palatable, and is slightly nourishing.

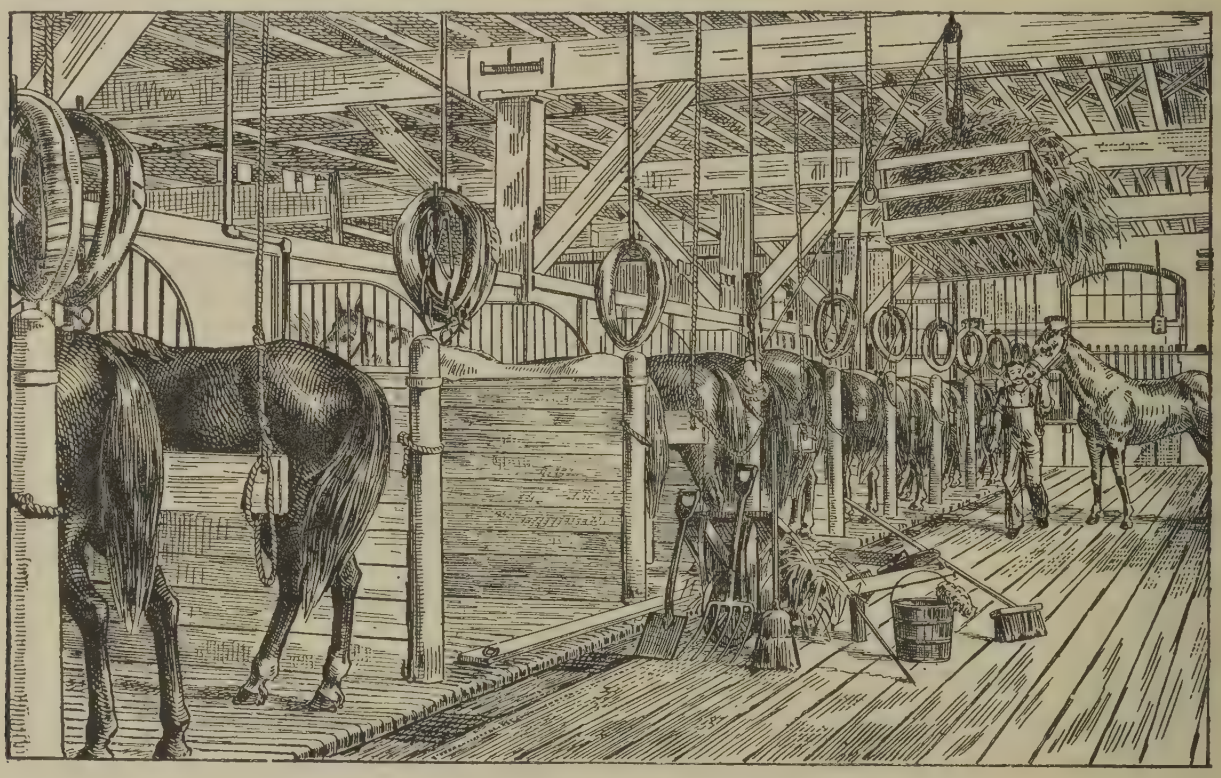


FIG. 283.—STALLS, DRYING RACK AND TOOLS.

In most localities it will be found beneficial to provide for filtering the water given to horses. A good filter may be made by filling a large barrel with coarsely ground charcoal with brush and gravel and a mixture of sulphur. This, placed above the watering trough, in position for leading the water through it will greatly reduce the cases of colic and kidney complaint among the stock (Fig. 282).

Stablemen are usually required to care for from fourteen to eighteen horses (sixteen is the average

number, the feed being mixed for them). Each one should be assigned his place in the stable and should be furnished with the usual kit of stable tools, including ratan shavings, from which to make brushes or wisps, and should be required to groom his horses twice a day at least. Too much grooming is hardly possible. The more a horse is groomed the better he feels, and, therefore, does better work. The horse millennium will be when each animal receives just the right amount of food at exactly the right time, and be cared for and groomed with regard to his own peculiar physical conditions.

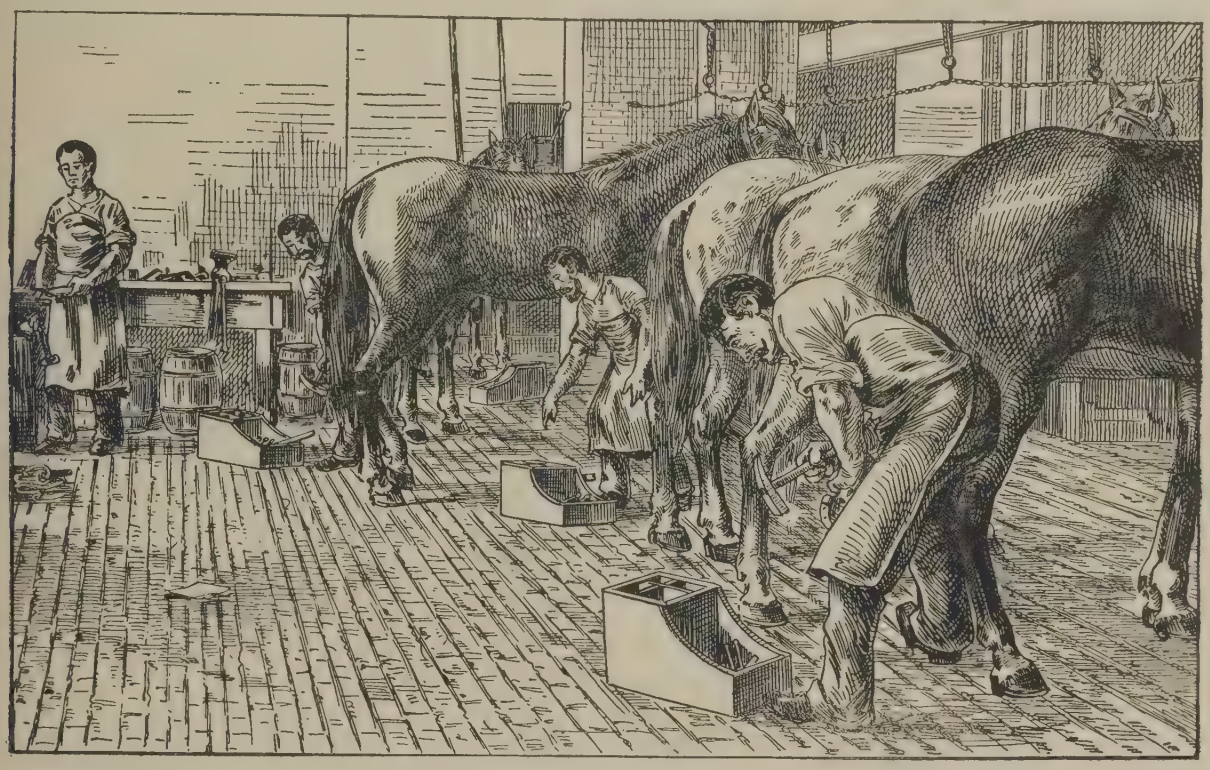


FIG. 284.—INTERIOR OF BLACKSMITH SHOP.

MILEAGE.

The daily mileage for street car horses is from ten to twenty-two miles. Ten miles with single cars and fifteen on double cars is about the standard distance, with one day in seven for rest. When horses are driven more than fifteen or sixteen miles a day it will be found difficult to keep them in good condition, and an attempt to exact more than than this from a team will not be found to be economical. In cool weather the distance may be covered in one trip, so that the horse may not be disturbed during the hours assigned for rest. When the weather is exceedingly warm it is better to divide the time, and if the stable is not conveniently located, relief stations should be established and provided with suitable shelter; not a mere booth or shed, in which they are liable to be drenched by a sudden shower or chilled by a change of temperature, or, worse than all, pestered by flies and harassed by restless companions, but a stable proper.

The fact is established beyond question, that the life of a car horse is prolonged from twenty to thirty per cent. by having a stable rest between trips, in summer, when the harness is taken off, and proper water applications afforded them.

Night horses should be kept in a separate and quiet department of the stable, and bedded so that they can sleep during the day.

BEDDING.

In fact, it is a good plan to keep more or less bedding under the horses during the day, especially with such animals as hesitate to respond to

Nature's calls when standing on a bare floor. Quietness is a desirable feature to be sought in a street car stable. On account of the noise, stone floors and iron gutter covers are not recommended. Neither are iron chains recommended for halters, especially where iron mangers are used.

The material used for bedding is regulated usually by the kind to be had. Hand thrashed rye straw is considered the best. Oat straw, rice straw, pine straw, prairie hay, wood shavings and Holland peat moss are used as substitutes. With any material a liberal supply should be provided. It is cruel treatment to a horse to put only a little straw upon a hard floor to make him a bed.

Where pine shavings are used they lessen the value of the manure as a fertilizer. Peat moss has its advocates; it is a good absorbent, and is usually economical. As a bedding for use in hospital stalls it is highly recommended. Every well regulated stable in which straw is used as bedding should be provided with suitable racks for drying and airing the bedding after being used. These racks are preferably constructed of narrow slats set edgeways for the bottom, and may be three or four feet wide and ten feet long, or large enough to hold the bedding for six or eight stalls. These should be suspended from the ceiling by a block and fall, so that they may be readily lowered to the floor for filling, and swung up and out of the way during the day. (Fig. 283).

Disinfectants should be freely used in every large stable, especially in warm weather. For this purpose phenyl, plaster, bluestone, lime partly air slacked, either alone or mixed with the above, are recommended. There are also patent mixtures and solutions on the market, some of which are in favor with stablemen as disinfectants.

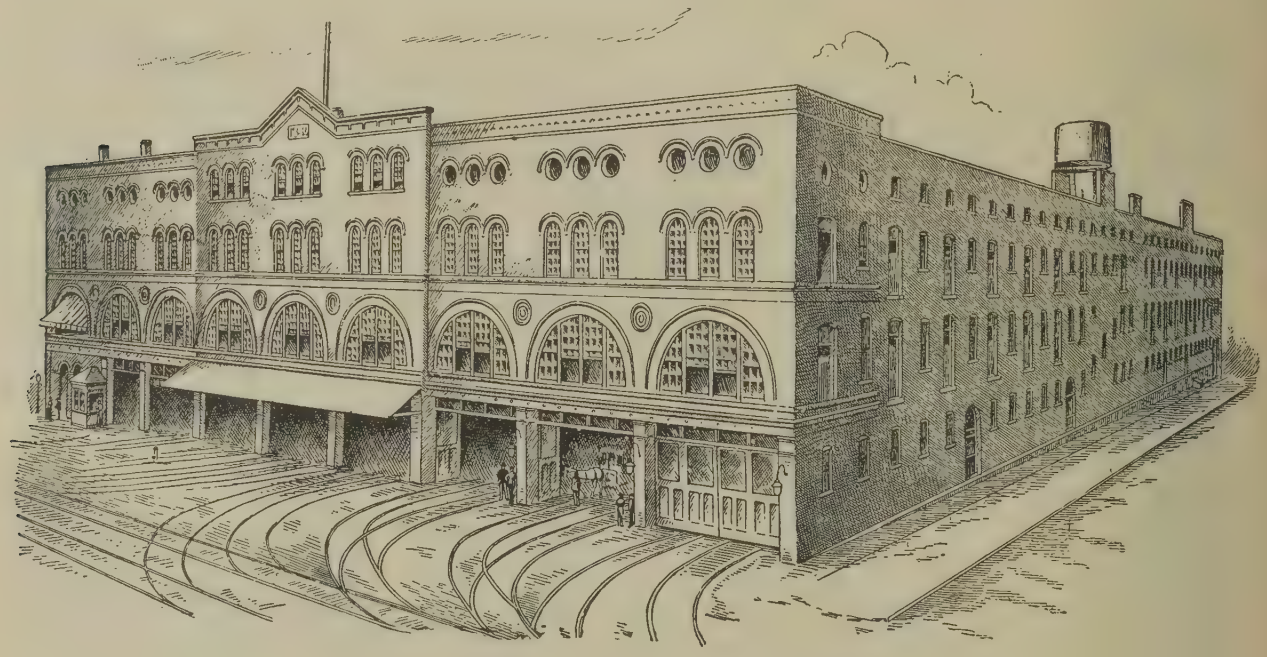


FIG. 285.—CITY STABLE—BELT LINE, NEW YORK.

Each driver should have his own stock and should be required to report at the end of each trip the slightest slip or bruise. When horses are constantly driven by one man they become accustomed to his voice and touch, and keep in better condition than when driven promiscuously.

SHOEING.

The shoeing (Fig. 284) is an important item in the expense account of horse roads, not only in the direct cost of the work, but indirectly from the losses that are likely to occur when the work is improperly done. The blacksmith department of a street railway, as a general thing, does not receive as much attention as it should from the management. Often the work is committed to the charge

of ignorant and incompetent men, and little attention is given to instructing them in all the details of their work.

Hardly any two animals can be shod exactly alike. The smith should study the condition of each foot, also any peculiarity in the gait of the animal, and suit the shoe to each case. One of the absolute requisites which constitute a good farrier is that he have some knowledge of the structure and formation of the horse's foot in all its parts, and for this purpose the manager of a street railway company should see to it that some work on farriery is provided, which all the employes of the blacksmith's shop, as well as the stable foremen should be required to study until they become proficient in the practice and art of horseshoeing. "Russell on Scientific Horseshoeing" is recommended as a good work for this purpose.

Some of the various brands of machine made shoes on the market are admirably adapted for use in street car service. It is difficult to specify which are the best. The selection depends upon the character of the path over which the animal is to travel, and the condition of the foot. A shoe made of soft iron will usually give a better footing on pavements than one made of hard iron, but it will not wear so long. Some roads keep two or three brands of shoes in stock, and use each as best suits the conditions of foot and streets.

Some horses wear out their shoes much faster than others, especially those that travel on the toes of the hind feet. In this case the shoes are worn thin at the toe and soon break, and the animal requires a new shoe every two or three days.

As to hot or cold fitting, opinions differ, and probably always will. On most lines hot fitting is the practice, although there is much that can be said against it. If it is carefully done so that the walls of the hoof are not charred too deeply by the application of the hot metal, it may be allowed. In any case the shoe must be fitted easily and solidly to the foot.

The nails should be driven into those parts of the hoof where the horn is strongest and toughest. In the fore feet these parts are in the front and along the sides to the quarters. In the hind feet the wall is strongest towards the quarters and heel. The nails should be turned out as quickly as possible, as the higher they go the less thickness of hoof is found. On paved streets the shoes last usually from sixteen to twenty days, unless they are accidentally torn off. On some hard lines the horses require shoeing, on an average, once in ten days, and in the winter season as often as once a week, and sometimes every three or four days. In this case the hoof becomes riddled with nail holes and great care is required in placing the shoe.

Flat shoeing with three-quarter shoes is preferable on paved streets, as it throws the weight of the horse upon the frog, and also tends to prevent quarter cracks and split hoofs. When horses are driven single to heavy cars, and where there are many curves in the line, it is often best to provide both heel and toe calks. In case heavy shoes are used on large horses it is of advantage to have them made with a clip, which turns up over the toe and helps to support the hoof. On dirt roads calks are necessary in the winter season. In case the foot is suited to them, horses may be shod with home made tips which will be found to give excellent satisfaction. The weight of the shoe should receive careful consideration. The extra pound which the animal is required to lift many times a minute, may exhaust his power more than the labor of hauling the car. Ordinarily the shoe should not weigh more than one and a quarter pounds.

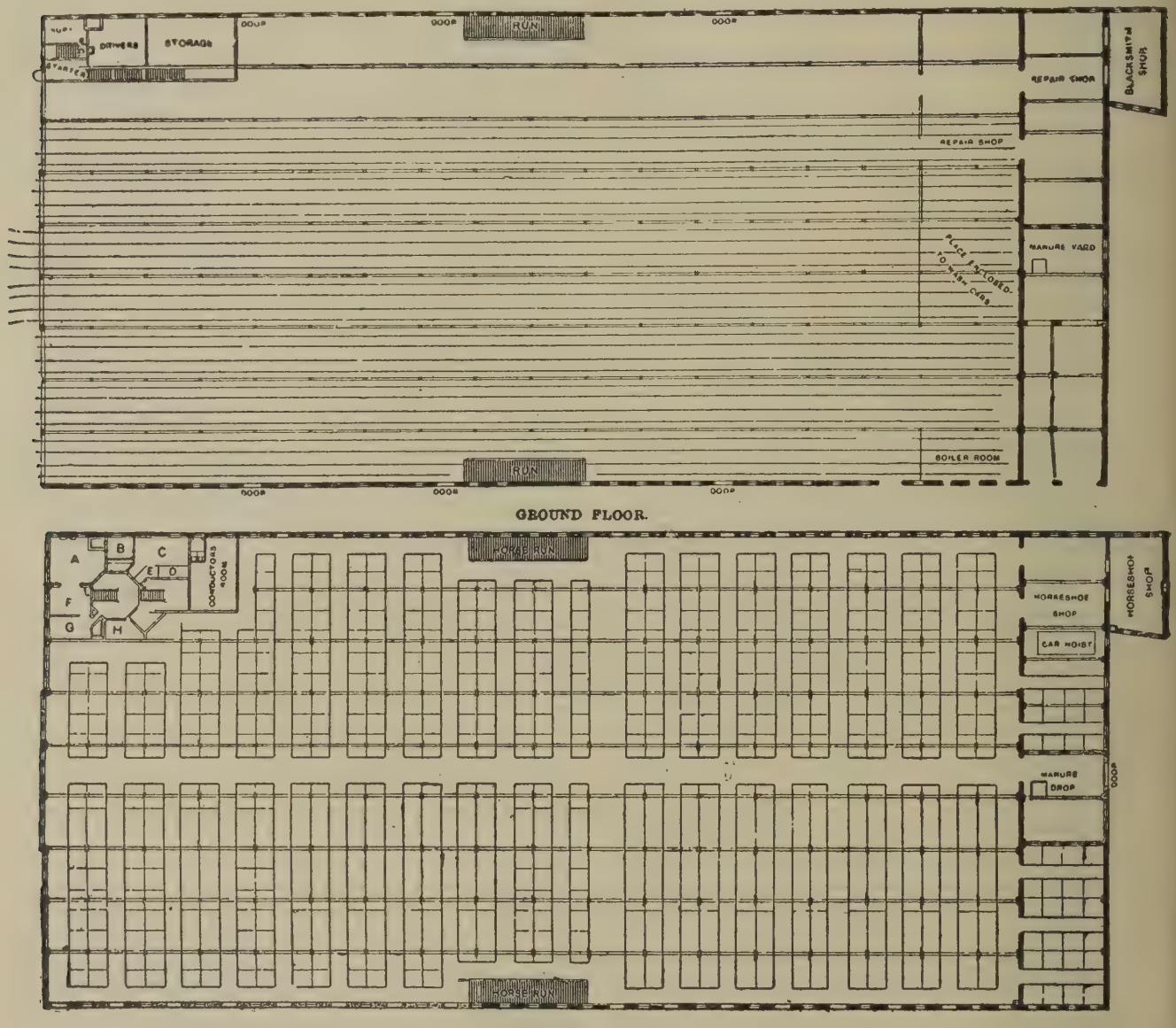
In case a horse has been foundered or has imperfect feet from any cause, it will be found of advantage to have him shod with the bar or round shoe. Horseshoe pads are recommended for some horses. Their use will often cure lameness and render a horse serviceable that could not work at all without them. It is recommended that a readily adjustable shoe be carried on each car for use in case a horse casts his shoe *en route*. These are easily strapped to the foot, and will prevent the hoof from being broken.

Care in the selection of the nails to be used is of more importance than the selection of the shoe.

Light, smooth, elastic wrought steel nails are preferable. In case cut nails are used, great care should be exercised in driving, lest an imperfect nail split or sliver at the point and a portion be driven through into the sensitive part of the foot. Careless nailing, or driving a nail into the quick and then withdrawing it and driving it again so close to the wound as to irritate it renders many a horse worthless. When this is done the horse may not show lameness for a day or two, when it is difficult to trace the cause.

STABLE.

There are stables and stables. Some are only stables, and are not worthy the name of a "horse home." The car horse usually passes twenty-one of the twenty-four hours of the day in the stable; hence the necessity for making him as comfortable as possible, both from the humanitarian and economical standpoints. It should be remembered that when a horse is required to resist suffering or annoyance of any kind, powers are demanded that could be utilized for hauling cars.



A—Prest.'s room. B—Treasurer's office. C—General office. D—Receivers. E—Paymaster. F—V. Prest.'s room. G—Consulting room. H—Lost articles.

FIG. 286.—PLAN SHOWING CAR HOUSE AND STALL ARRANGEMENT IN CITY STABLE.

It is not our purpose to suggest a model for an ideal stable, for conditions in city and country differ so widely that no uniform practice can be recommended, except along certain lines. So we shall have in mind the three or four story city stable and the one floor structure of the country stable. Figs. 285 and 286 are elevation and plans of a large city stable.

From twelve to eighteen feet is a desirable distance to have between the floors of deck stables. The monitor roof of one story stables should not be built too high, for it is difficult to keep such structures sufficiently warm in cold weather.

The arrangement of ventilators or flues should be such that when open a cool draught will not strike directly upon the animals. There should be roof

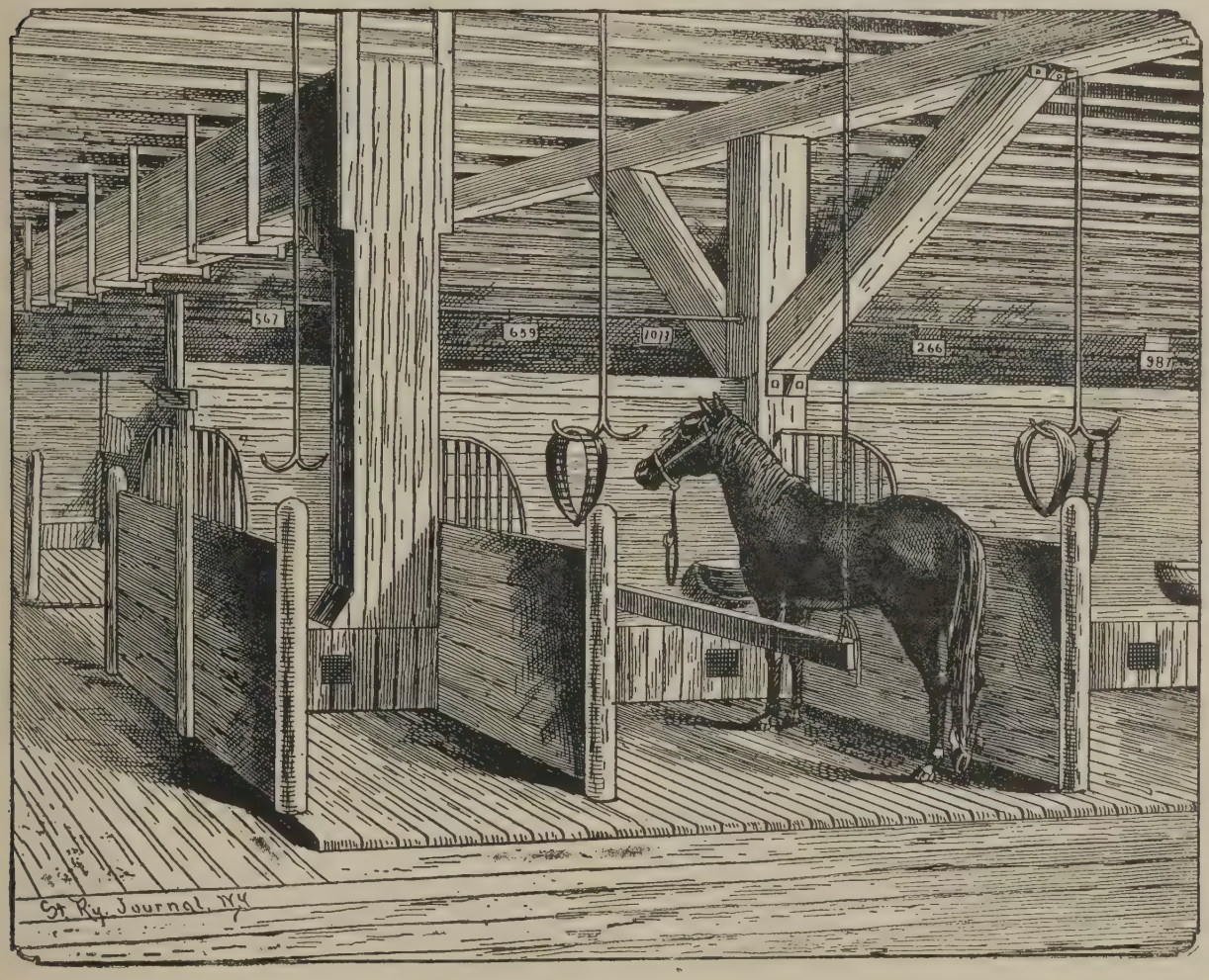


FIG. 287.—MECHANICAL FLOOR VENTILATION.

Ample ventilation, light and cleanliness are the essentials of every street car stable. Provision should be made in every stable for admitting from 8,000 to 10,000 cu. ft. of pure air per hour for each animal. Some claim that a much less quantity—from 350 to 400 cu. ft., or six times as much as for a man—will answer, while others provide for admitting as much as 30,000 or 70,000 cu. ft.

ventilators over the cross gangways and side doors at the end of the gangways. In high stables it is a good plan to provide a "tell tale" weather vane that will indicate on each floor the direction of the wind. In case the wind blows too strongly in one direction the doors and ventilators on that side of the building can be closed while air is admitted from the opposite side. The tell tale is usually

made by mounting the outside wing on the end of a vertical shaft, to which, on each floor, is attached an arm or arrow.

The sash and ventilators in the deck of monitor roofs may be readily opened and closed by means of cords properly attached and hung in position to be readily reached from the floor.

Air shafts which run above the roof should have on the outside movable slat sides that may be shut against the direction of the wind and opened with its current, in order that downward draughts may be avoided, and suction for the removal of the heated and impure air promoted. Wall flues should be provided with a gas jet beneath to increase the flow of air.

of perfect ventilation the foul air must be taken from the floor level.

An illustration of this practice is given in Fig. 287, from which it will be seen that the trunk flues are supported from the ceiling and connected by risers with a horizontal flue that is located on the floor level along one side of the head partitions beneath the feed boxes, having screened holes six inches square opening into the adjacent stalls near the floor, through which the foul air is drawn. The flues are constructed of narrow pine boards tongued and grooved, the joints being rendered air tight by white lead. The size of the tubes is carefully gauged for the number of cubic feet of air they are required to carry, depending on their loca-

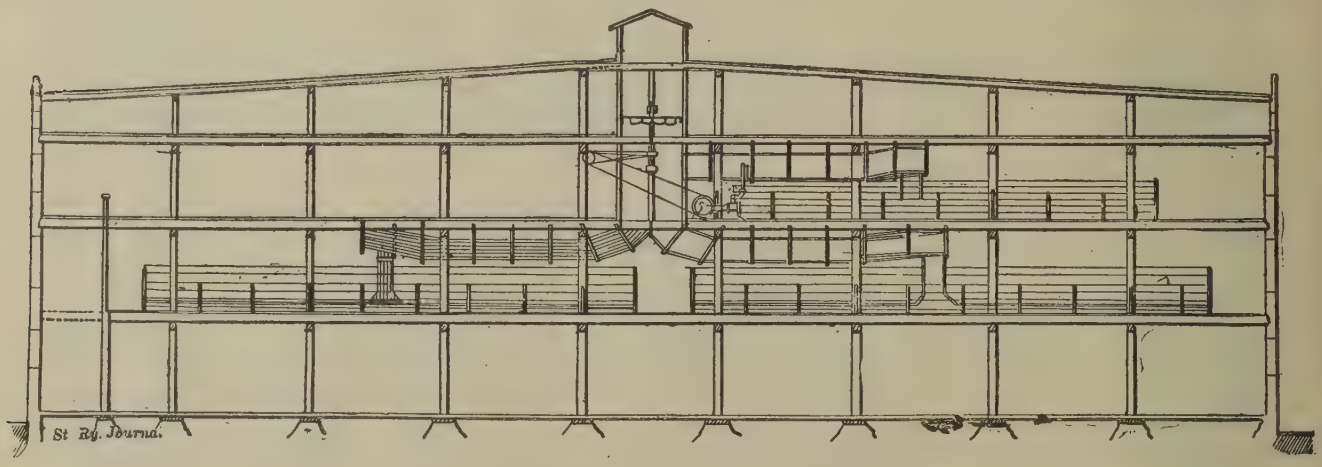


FIG. 288.—MECHANICAL FLOOR VENTILATION.

Mechanical ventilation is recommended for very large stables. This consists usually of an exhaust fan or turbine, operated by means of steam power, in a central shaft from which large sheet iron or galvanized iron pipes are led along the ceiling, with openings just over the stalls. In warm weather this system may be used to good advantage to increase the ventilation.

In some stables where mechanical ventilation is employed the inlet flues are placed on a level with the floor. The theory on which this practice is based is that where the inlet is placed above the heads of the animals, the most deleterious gas, being heavier than air, will not rise to the ventilating flues. (The specific gravity of carbonic acid gas, $C.O_2$., is 1.529) so that to meet the requirements

tion from the fan, growing larger as they approach the outlet which is through the monitor roof near the centre of the stable.

Fig. 288 is a section elevation of a stable, showing the location of the trunk flues and risers, the fan and engine or electric motor by which it is operated. The flues at their junction with the fan chamber are 4×6 ft. In practice it is found that an eight foot fan running at 150 revolutions per minute, is capable of removing 161,000 cu. ft. of air per minute.

Light is as acceptable to horses as to man, and windows should be amply provided. Provision should be made, however, for shading the glass so that the stable may be darkened in hot weather to prevent the animals from being pestered by flies.

The stalls may be constructed on the ground floor or, equally well, on the second or third floor, provided these are constructed water tight, with ample drainage, and provided with runs connecting with the ground in two or more directions. The material of which the stalls are constructed should be such as will be least likely to absorb or retain impurities. The stalls are preferably made double, with a swing board between the animals, and should be at least eight and a half feet wide and

It is a good plan to construct the false floor of the stalls with slats, made into trap doors, with hinges at the sides. These can be readily raised when it is necessary to clean or flush out the floors.

It is not essential that the entire stall floor should be made of slats. About three feet from the head the floor may be laid solid and the remainder with slats. The waterproof floor may be given an inclination from the head to the foot and the

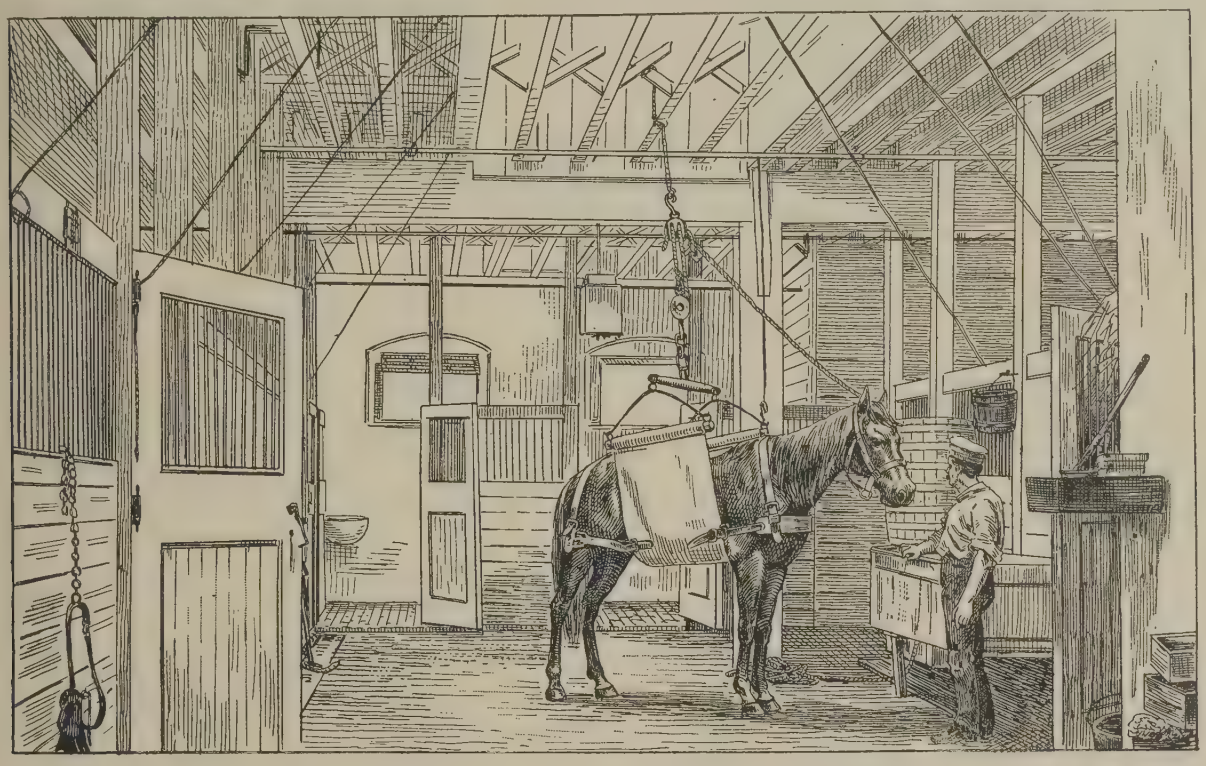


FIG. 289.—HOSPITAL, STALLS AND SLING FOR DISABLED HORSE.

not less than nine feet deep (Fig. 287). Single stalls when made should be from four to five feet wide.

The side partitions should be not less than four feet high, rising still higher at the head or furnished with screens, so that the adjoining animals cannot annoy each other. The floors are usually constructed of some close grained wood like maple, cut into strips four or five inches wide and two inches thick, placed about three-fourths of an inch apart, so that the urine can pass off without being absorbed by the bedding. The floor should incline about two inches from front to rear.

slats may have a thickness of three inches at one end and two at the other, so that the animal will stand on a level floor.

The floor may be rendered water tight by covering it with a layer of building paper and roofing felt cemented together with asphalt cement. The gutters are preferably made of 4 × 12 ins. timbers scooped out and laid with sufficient pitch to insure perfect drainage. These may be covered with a closely fitting plank with grating to admit the liquid. Near each end of the plank a ring is attached for convenience in lifting when it is necessary to flush out the gutters.

It is customary in some sections of the country, where the climate is mild, to allow the animals to stand on the ground where the soil is suitable. In this case no drainage is required as the soil absorbs the moisture. In case the soil is of such a nature as not to absorb the moisture readily, a small keg may be sunk flush with the floor, and covered with slats, above which the bedding may be placed. From these the drainage may be dipped as occasion may require.

Dirt floors, however, are not recommended for any climate; they are not readily cleansed, and are liable to become very impure.

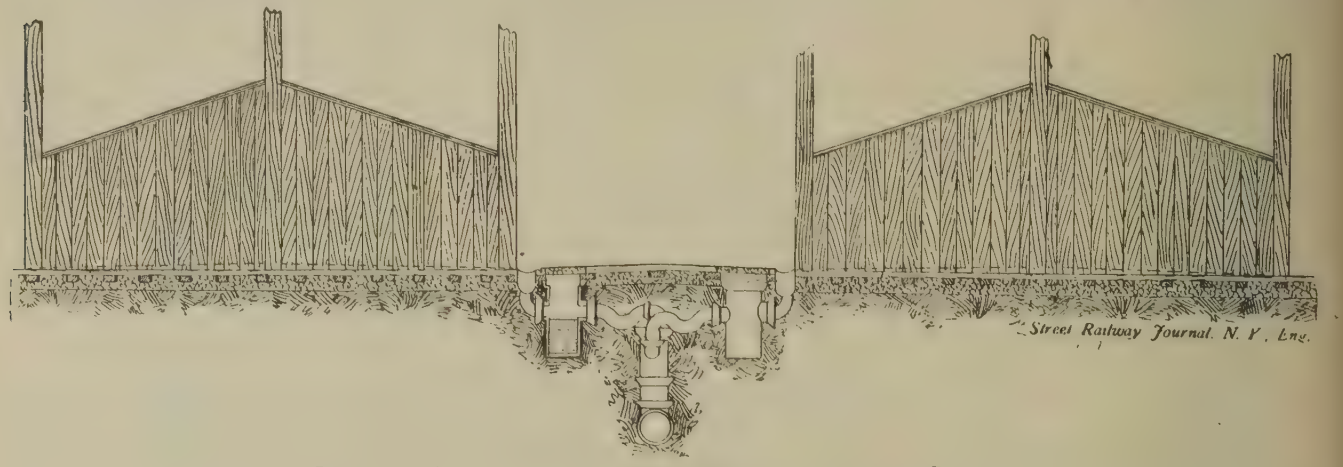


FIG. 290.—CROSS SECTION, STALLS AND CATCH BASIN IN STABLE.

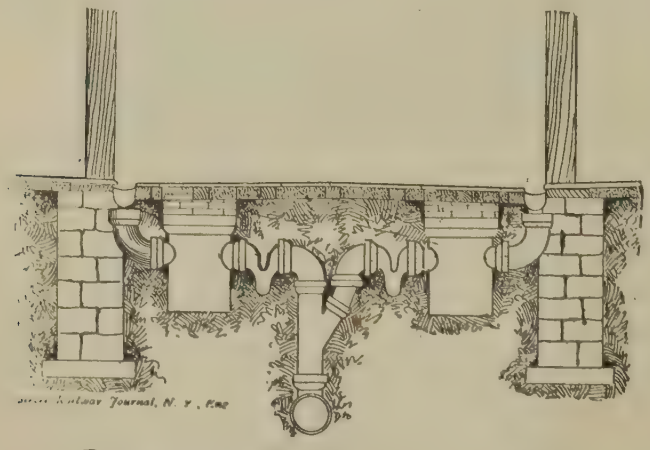


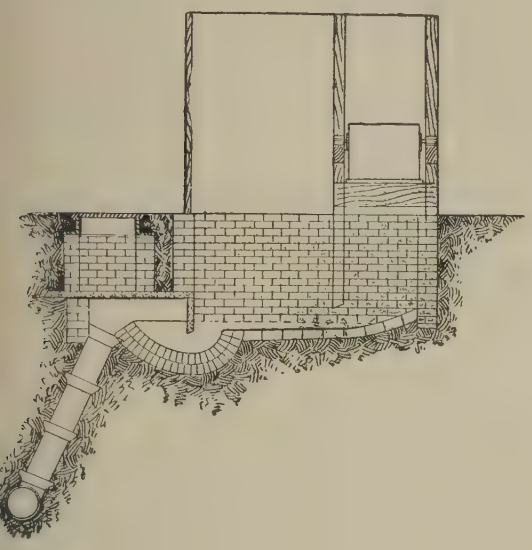
FIG. 291.—CROSS SECTION OF CATCH BASINS.

The arrangement of stalls is an important matter. They may be placed facing each other with a solid partition between the heads of the animals or, what is preferable, with a gangway between, sufficiently wide for the feed cart to pass. With this arrangement the feed may be placed in the manger through an opening in the partition and the danger of the stablemen being kicked by vicious animals is avoided. This arrangement also improves the ventilation. It is not a commendable arrangement to place the stalls facing a dead wall. In case the stalls are made facing each other, the end partition may be omitted and the feed trough may consist of a box running lengthways of the stable. In this case the feed cart can be mounted on a narrow gauge track above the trough, from which each animal can be served as the cart is run along the track.

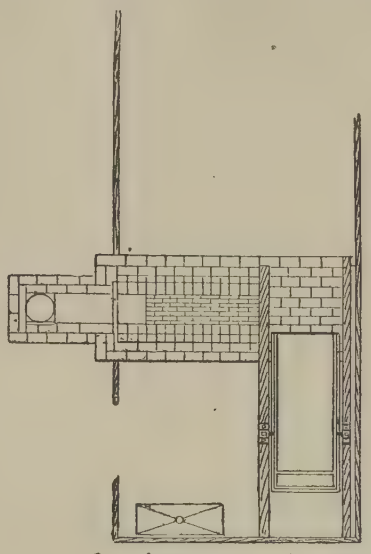
The hospital should be separated from the stable by a wall, or it may be in a detached building. The stalls should be amply large, at least 12 × 16 ft., and have high partitions (Fig. 289). Slings should be provided for weak and disabled animals and there should be provision for giving foot baths. Low boxes made of plank, about a foot deep, placed in a narrow double ended stall with suitable hitching posts, make excellent foot baths. They should be so arranged that the animal can stand with either his fore feet or hind feet or all in the bath.

The drainage is an important matter and should receive careful attention in the building of every new stable. The traps and catch basins, whether they lead into city sewers or into cesspools, should be well ventilated so that the foul gases may be carried outside the stable. It is also recommended that the overflow pipes from the water troughs be led into the gutters so that the waste water will assist in flushing them out.

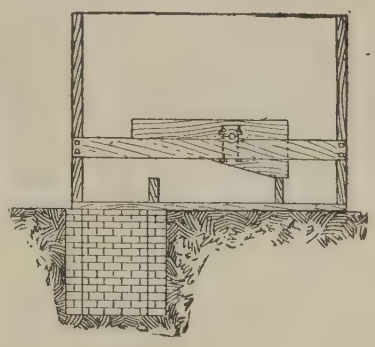
Suggestive details for drainage construction will e found in the accompanying illustrations, Figs. 90 to 293. It is recommended that cast iron pipes are clearly indicated, and do not need a description, neither do the plans of the buildings, as the name indicates the purpose of each.



Section of Vault, Trap and Reservoir.



Plan of Vault and Flushing Reservoir.



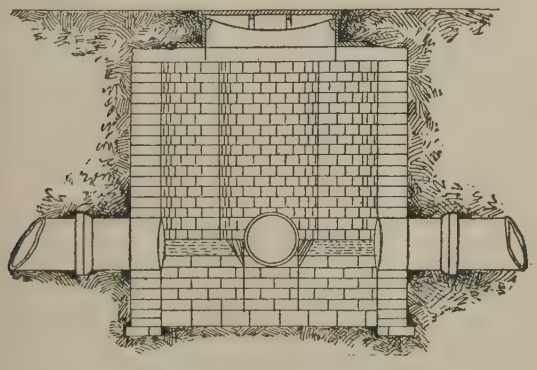
Elevation of Flushing Reservoir.

Street Railway Journal. N. Y., Eng.

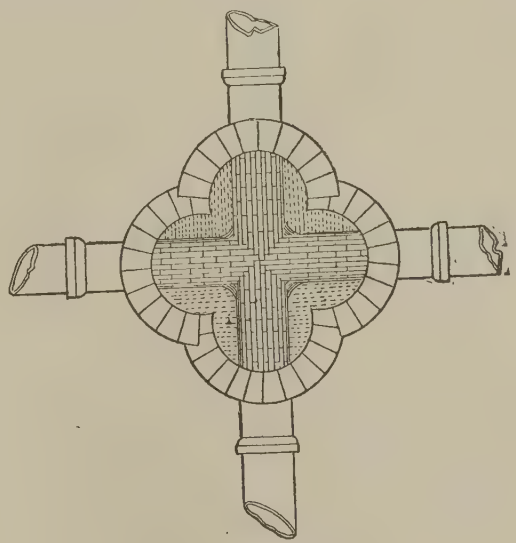
Fig. 292.

e used for stable drains instead of brick or tile, or the reason that it is difficult to make the latter vater tight, and besides, the foul gases will escape hrough the pores of the material. The joints of ron pipes, especially of those that convey the quids from the upper floors, should be made tight y the use of some material other than lead, be- ause the uric acid will soon destroy the lead and ause the joints to leak.

Figs. 296, 297 and 298 are elevation and floor plans of a stable suited to a medium sized city. In this particular stable the first floor is used for a car house, and the stable floor is covered with artificial stone. Numerous iron drain pipes are provided and these are led down to the ground from the second floor at the side of the supporting posts.



Cross Section of Manhole.



Plan of Manhole.

Fig. 293.

Figs. 294 and 295 are suggestive ground plans for country stables where land is cheap, so that separate buildings may be provided for the different departments. The locations of the drains and cesspools

The positions of transfer table, engine room washroom, etc., are clearly indicated.

Figs. 299 to 302 afford further studies in stable, car house and blacksmith shop building, suitable for branch lines or main lines of small cities. The material is wood with shingle sidings, and the architectural effect is pleasing. The blacksmith department in this case occupies a detached building in rear of the stable.

The manure pit, for city stables, is preferably made of brick, with dead walls to shut it off from the other portions of the stable. It should have ventilating flues extending above the roof. A door near the base should be provided in a convenient position for placing the carts when loading and should have a chute leading to each floor, provided with covered hoppers or doors through which the stablemen can readily dump the refuse from their wheelbarrows. The doors should be weighted to close automatically. The pit should be emptied before the contents have had time to heat and steam. Where provision is made for carting away the manure every day no pit is necessary and the chutes may be placed at the ends of the gangway and lead down to the stone pavement in convenient positions for loading the carts. When the manure is stored in piles outside the stable these should be sufficiently removed from the stable proper to prevent the escaping gases from entering the building.

It is not a commendable practice to locate the hospital pen adjacent to or about the manure pile where the invalid horses will be compelled to stand upon the heap and breath the escaping gases.

It is the practice in some stables to so train the mules and horses that they will visit the manure pile at stated intervals, especially after coming in from a trip, and there attend to Nature's calls, thus greatly relieving the drain equipment and reducing the hostlers' labors.

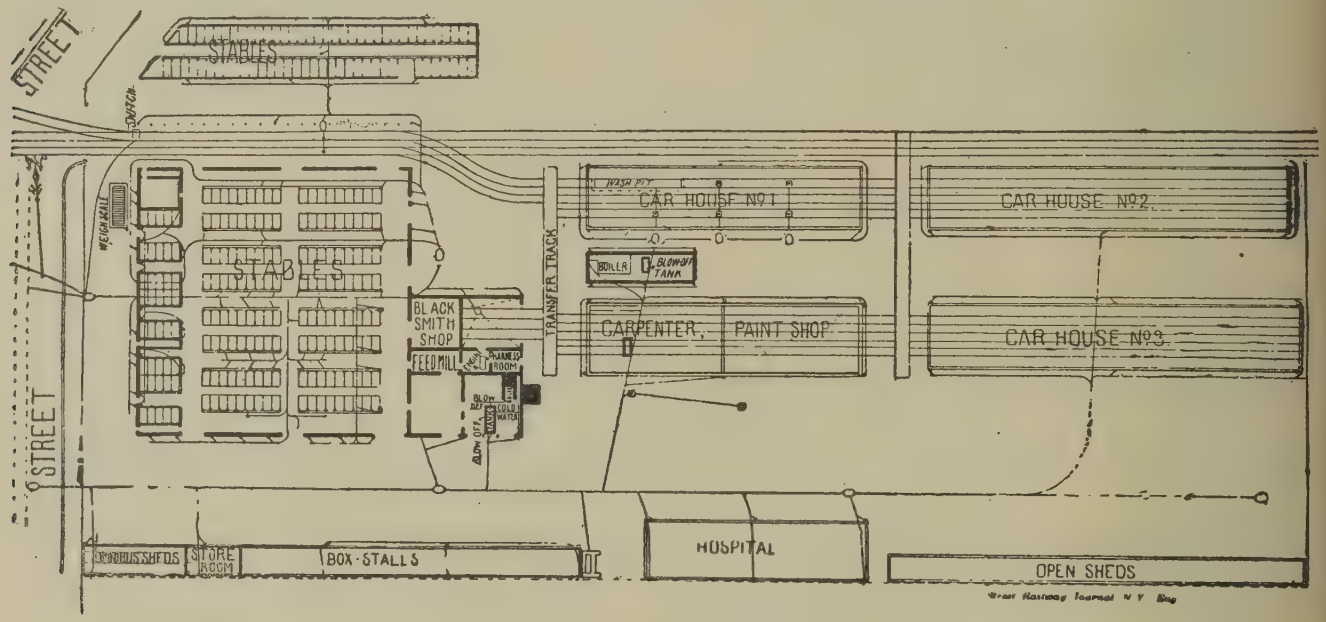


FIG. 294.—RELATIVE POSITIONS OF STABLE AND OUTBUILDINGS.

The income from the sale of the manure depends upon the location. Where there is any demand for it as a fertilizer it usually brings from $2.00 to $4.00 per year, per horse. In most Southern and Western cities, however, the companies usually have to pay for having it carted away. A commodious yard should be provided adjacent to all stables, where the invalid horses may be turned out for air and exercise, and another should also be provided where all the animals can occasionally be allowed to roll and walk about. In the case of mules it is absolutely necessary to provide a place for them to roll or "wallow." It will tend to keep them in good health and will lessen the labor of the grooms.

n addition to the stable yard, as above recommended, it is desirable that a street car company n or control a farm of from fifteen to thirty es, located at a convenient distance from the y, where the animals may be turned out to past- when necessy, and where the nsioners may n at large.

The runs, as eviously stated, ould lead out om the upper ors in two or ore directions. ese are preferly constructed ithin fireproof alls and should t be too steep. e floor should reinforced with oden strips two three inches ide and two ches thick, to event the animal om slipping, and provide a suport for the litter ith which the run ould be covered. he most durable aterial that has een found suitble for this purose is leather scrap, when it can be obtained. It sually lasts from two to three years, and is not adily ground into dust as is the case with straw, n bark and peat moss. On one side of the run a ne of narrow stairs or steps should be provided r the use of the employes.

Protection against fire is a subject that is natrally treated in connection with the runs, and here the building is not absolutely fireproof there are many precautions and devices that may be recommended. A large building should be divided into sections by brick walls with fireproof doors that will close automatically. The doors may be held open by a rope or chain having a solder link that will fuse at a low temperature. The blacksmith shop, paint shop, repair shop, and oil room should always be shut off by fireproof walls and doors. The stable should be lighted, when possible, by incandescent electric lights. The next best light is gas. When oil lamps are used they should be of the safest pattern and carefully shielded by noncombustible material.

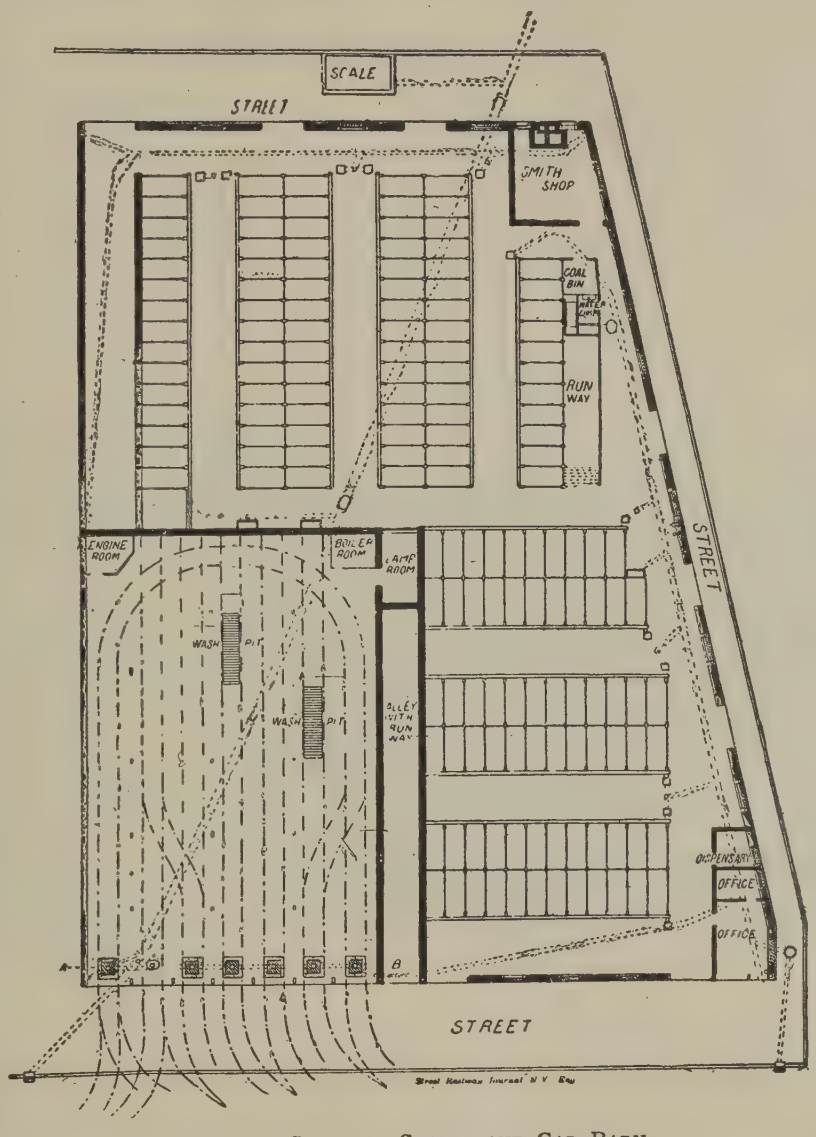


FIG. 295.—COMBINED STABLE AND CAR BARN.

An unhitching device is also very important. One that is cheaply constructed consists of an iron rod three-fourths of an inch in diameter, running through a line of stalls attached to the front of the feed box, and terminating in a crank at the cross gangways. A curved hook is riveted into this rod at each stall over which the halter ring may be placed. When the rod is in a certain position the end of the hook is held against the front of the feed box and the ring cannot readily be removed, but by turning the rod half over the ring drops from the hook, and all the horses on the line are at once released.

The same result may be accomplished by means of a sliding rod operated by a lever at the cross gangway.

Hand grenades, fire buckets and chemical extinguishers should be kept in suitable positions, as supplemental, of course, to a stand pipe and hose which should always be provided. This can be fed from the city main or from tanks on the roof. All the fire apparatus should be frequently inspected to see that the materials do not deteriorate and that all are always in good condition. Next to having a fireproof building, the safest provision is to have the stable equipped with some one of the well known automatic sprinkling devices. These usually consist of a network of pipes supported from the ceiling, and supplied from a tank on the roof. There are two main systems, the dry pipe and the wet pipe; in the former the pipes are kept full of air under pressure, which must be daily renewed. This is to obviate the freezing of water in the pipes. In the wet pipe system the pipes constantly contain a fire extinguishing and non-freezing compound. At intervals of ten feet or less throughout the system there are sprinkler heads with valves held in place by solder joints, which are very sensitive to heat, and will melt at from 156 deg. F. up to 300 degs. When the joint is melted the sprinkler is opened, and with the wet pipe system the fluid is discharged at once. With dry pipes the air has to escape first, but this is very rapid and then the water follows, and, in all of the systems, is discharged in a fine mist or spray, so dampening everything within a radius of fifteen feet or more of the open sprinkler as to extinguish or prevent the spread of the flames.

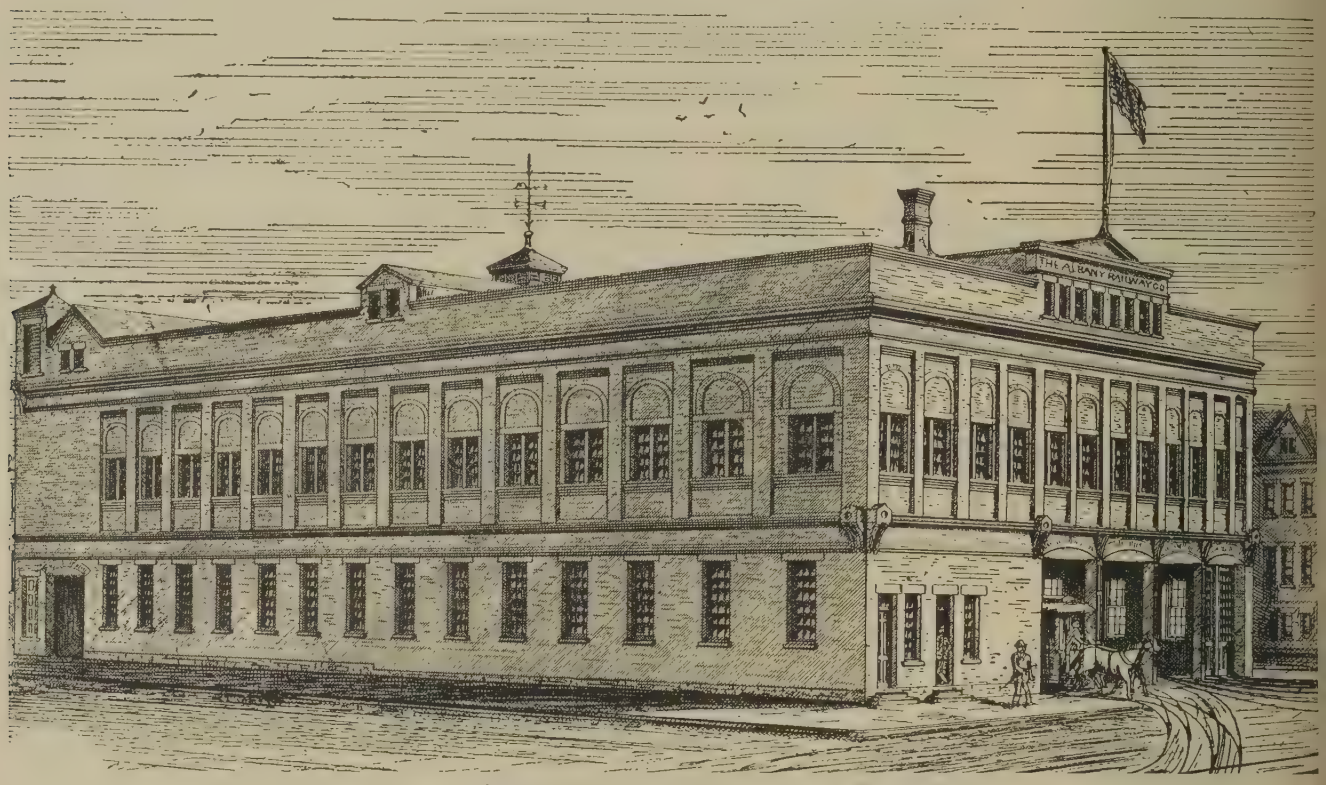


FIG. 296.—STABLE AND CAR HOUSE—ALBANY RAILWAY.

In addition to other fire precautions, every well regulated stable will maintain a system of fire drills, when, at a given signal, all the animals will be unhitched and removed from the building. The drill is necessary in order to train both the men and animals, so that the building may be vacated in the shortest possible time. There is no single feature of a horse railway system, large or small, that should be so carefully planned and made safe as the stable, and the importance of properly protecting it against fire cannot be urged too strongly, for

in case a stable and horses are destroyed by fire, no amount of insurance will pay the losses consequent upon a necessarily extended suspension of business while new horses are being purchased and trained, even though the value of the stable itself may be made good.

Cleanliness is a not less important matter in the management of a stable than the drainage and fire precautions. It is not sufficient alone that voidings of the animals should be promptly removed and the drains flushed out, but there should also be a free use of disinfectants and whitewash. All the woodwork should be frequently whitewashed, as it gives the stable a bright appearance, and the lime has some deodorising properties. It is a mistake, however, to whitewash the walls of a stall, especially those where diseased animals have stood, without first washing them thoroughly with corrosive sublimate or some other germ destroying liquid. For the whitewash will not destroy disease germs, but often covers them up, where they are preserved for a long period, and a well horse being placed in the stall is likely to lick off the whitewash and introduce the germs into his system.

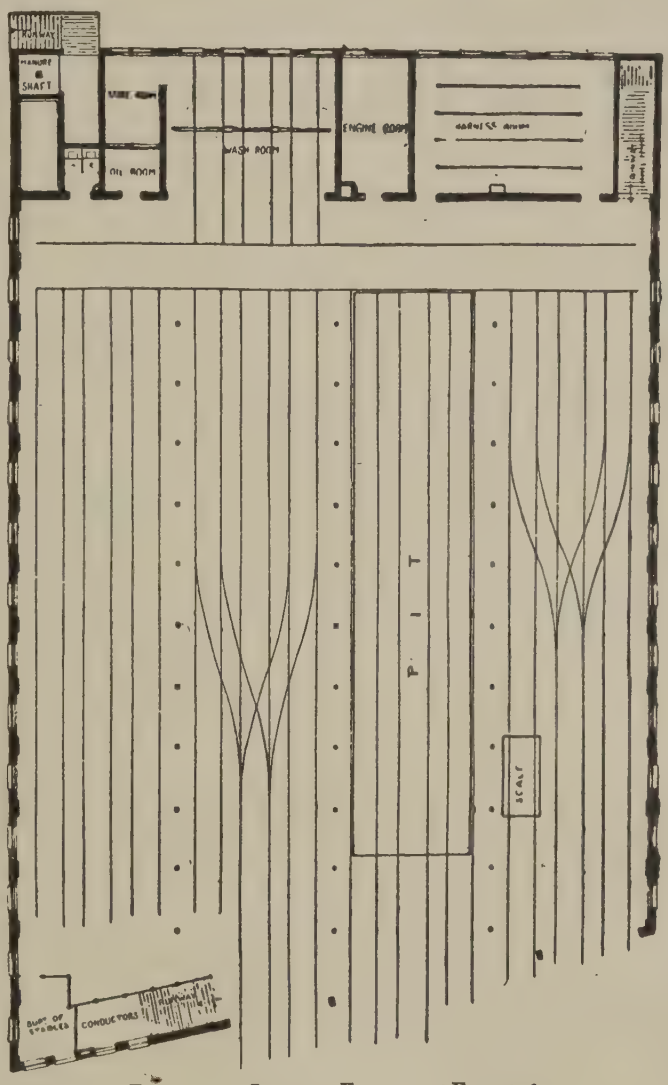


FIG. 297.—GROUND FLOOR OF FIG. 296.

The feed loft usually receives less attention than other portions of the stable, but it is important that it should be properly equipped and carefully attended. The floors, partitions and doors should be air tight to prevent the feed from becoming impregnated with the stable odors. The hay cutter should be separated from the main floor and provided with an automatic dust collector. It is not a commendable practice to allow the dust from the cutting machine to settle back upon the hay and grain; neither is it just to the employes whose duty it is to attend to this branch of the work, to compel them to live and perform their labor in the cloud of dust that is the necessary accompaniment of this work, unless provision is made for its removal. Where large quantities of hay are cut, an endless belt conveyor is an essential adjunct to the equipment. This may lead to a store loft or directly to the feed box.

Ample floor space should be provided for storing the grain so that it is not piled too deep. In case it is stored in deep bins, provision must be made for transferring it frequently from one bin to another to prevent heating. All large stables should be provided with a system of grain elevators, so arranged that the wagons upon which it is transported may discharge their contents into weighing boxes on the ground floor, from which it is lifted to the loft and distributed by means of spiral conveyors.

The grinding mill may be located in the loft or on any of the floors, and the grain may be led to it by means of chutes, and removed to a bin or the feed box by an ordinary grain elevator. Any of

the well known mills may be employed for grinding the grain; either the ordinary burr-stone mill, the Caswell, or the roller mill will answer the purpose. In any case the feeding chute or hopper should be provided with a magnetic separator for the purpose of collecting nails or any bits of metal that may be in the grain. These separators do the work very effectually.

The ordinary platform elevator for raising the hay and straw to the loft is an important part of a stable equipment. This may be done, however, by block and fall where the quantity is not too great. There should also be a platform hay scale located near the elevator, upon which all loads can be weighed.

The power for grinding the grain, cutting the hay and operating the elevators, may be horse, utilized by means of an endless tread sweep, a steam or gas engine, or an electric motor. When steam power is used the boiler and engine should be located in a separate building or at least in a fireproof portion of the stable.

The superintendent's office and an office for the receiver should be provided at such stables as are most conveniently located. Frequently, however, it becomes necessary to locate these offices in separate buildings, and often in the business portion of a city.

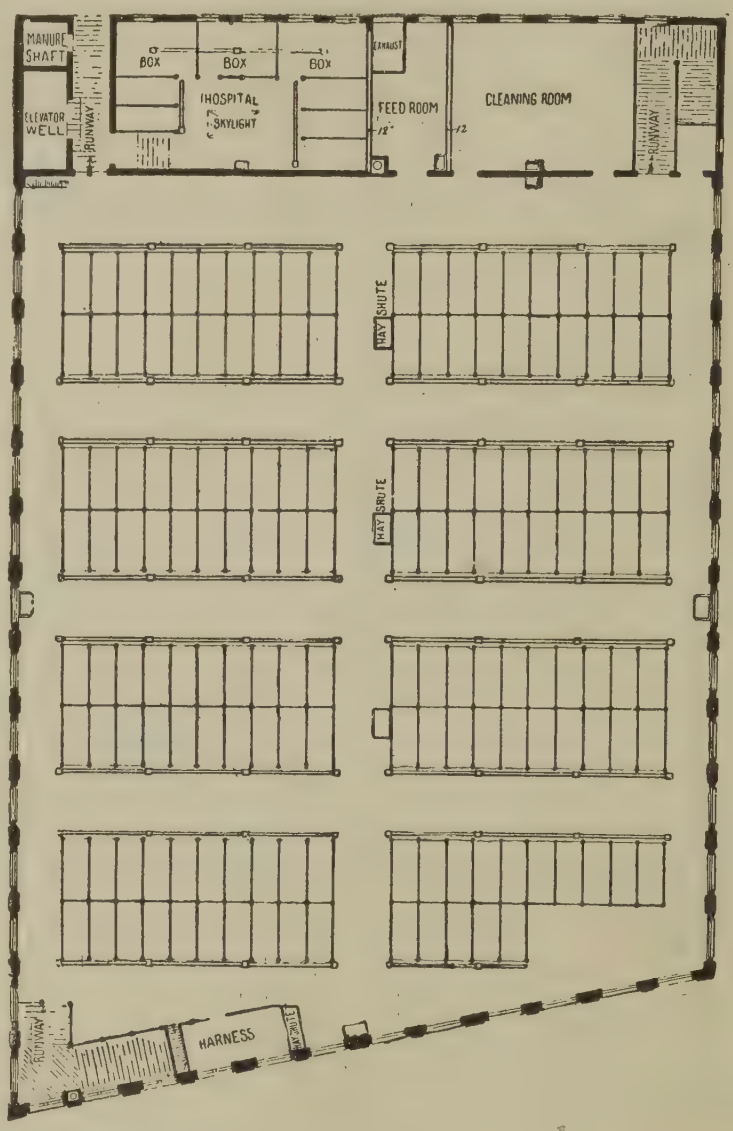


FIG. 298.—SECOND FLOOR OF FIG. 296.

Suitable offices to serve as headquarters, and to provide accommodations for the managers and the clerical force, should be included in the plans of some one of a company's stables. These should be partitioned off and have a hall, if possible, separating them from the stable proper. The arrangement and furnishing of these rooms will depend upon the taste and financial ability of the company. They should be light and airy, and divided into reception room, office proper and private rooms. The usual office furniture, including fireproof safes, should be provided and there should be ample toilet accommodations both for the officers and the clerical force. The location may be on the first floor, but preferably on the second.

A waiting room for passengers, properly furnished and warmed in winter, should not be omitted in the construction of such stables as are located near the terminals of a line or at points of transfer. Rooms for conductors and drivers should be separated, where possible, and each should be cheerful and comfortable with suitable furniture, lunch tables and tables for books and games. Lockers should be provided for caps and clothing and there should be ample washing and sanitary accommodations. Boot-blacking boxes and shelves for books and racks for papers should not be omitted

in the furnishing. These rooms should be frequently inspected by the superintendent and officers to see that they are kept in good condition.

An office conveniently located and properly furnished should be provided for the stable foreman. There should be desks and lockers for the safe keeping of books and records. In case a veterinary is not employed the foreman's office or a room convenient to it should be fitted with shelves and closets suitable for storing medicines. A full supply of popular remedies should always be kept in store, depending upon the school of practice, whether allopathic or homœopathic.

soon destroy the paint on the cars, and the unpleasant odors will cling to the cars while they are out upon the line. In case the ground floor is used as a car house, the floor above should be rendered absolutely water tight to prevent the stable drippings from coming down upon the cars. It is a good plan to construct the ground floor with sufficient grade to run the cars out by gravity. The washing pit is an important adjunct to the car house, and should be constructed with a waterproof floor, have ample drainage facilities, and hose convenient for supplying the water. Where the washing is done on other than the first floor, the

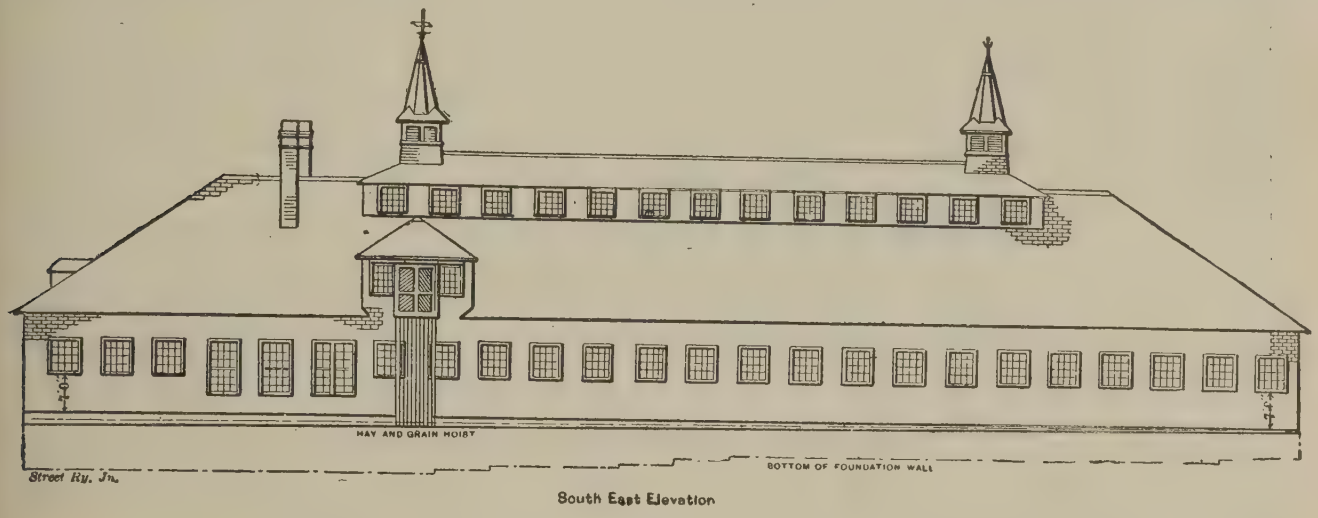


FIG. 299.—STABLE—UNION RAILROAD COMPANY, PROVIDENCE, R. I.

The oil and lamp room should be enclosed in fireproof walls or should occupy a separate building at a safe distance from the stable.

It should be a rule of every stable that no employe should ever enter the oil room with a lighted lantern or lamp, and the same rule should hold as to the hay loft; neither should smoking ever be allowed about the stable.

Bins or pits should also be provided for storing salt and sand.

CAR HOUSE.

The car house is perferably located on the ground floor, but any of the floors may be utilized for storing cars, provided there is an elevator equipment for lifting them, and provided the floor is shut off and protected from the stable odors. This is an important measure, for the stable gases will

track over the pit should be elevated so that access may be had to all parts of the running gear. It is not a mark of good management to run dirty cars. They should be cleaned daily, not only inside but outside and underneath. It is not uncommon to see cars running day after day with an accumulation of "dry" mud upon the brake and running gear equal to the weight of one or two passengers.

In connection with the wash room in stables where steam boilers are not employed, water heaters should be provided, so that there may always be a supply of warm water, either for washing cars or for use in the hospital department, or for washing harnesses.

A suitable transfer table, or car with a crossover track, is a part of the necessary equipment of every car house. The track is preferably located

at the back of the floor or, in case of a very long building, may be used in the middle. The transfer

FIG. 299A.—FRONT ELEVATION.

may consist of a simple, home made car, or a series of turntables may be arranged along the crossover track in line with each of the main tracks. There are upon the market various patterns of transfer tables, which have some advantages over the home made articles. Of these, the ones that operate on a level with the main floor without a pit are generally considered preferable (Fig. 302). Where a pit is required, care should be exercised to prevent men and animals from falling into it, and also to prevent cars from being derailed by it.

A suitable room should be provided for the harness department, where harnesses can be made, cleaned and repaired. This department should be in charge of a competent harness maker, one who will be economical in the use of stock, and should be provided with all the necessary tools for doing the work in the best possible manner. The collars may be manufactured or bought; opinions differ as to the economy of either practice. Ample store room should also be provided, with proper shelving, so that a full line of car and harness trimmings and other supplies may be carried. The store keeper will find it convenient to have arranged upon the walls of his office samples of everything in stock, properly numbered, to which he can refer when ordering new goods.

REPAIR SHOP.

The repair shop may occupy a part of the main stable or be located in a separate building. If in the main structure, it should be separated, as before stated, by fireproof walls and doors. The shop equipment will depend upon the amount of work to be done. Where the repairs for an entire system are made at one station, there should be provided a full complement of iron working and wood working tools, and a power plant for operating them. The wood working department should have a system of exhaust pipes for removing dust and shavings, and will necessarily have drying kilns for seasoning the lumber. Fig. 303 illustrates a floor plan of a repair and paint shop in which everything is arranged in the handiest man-

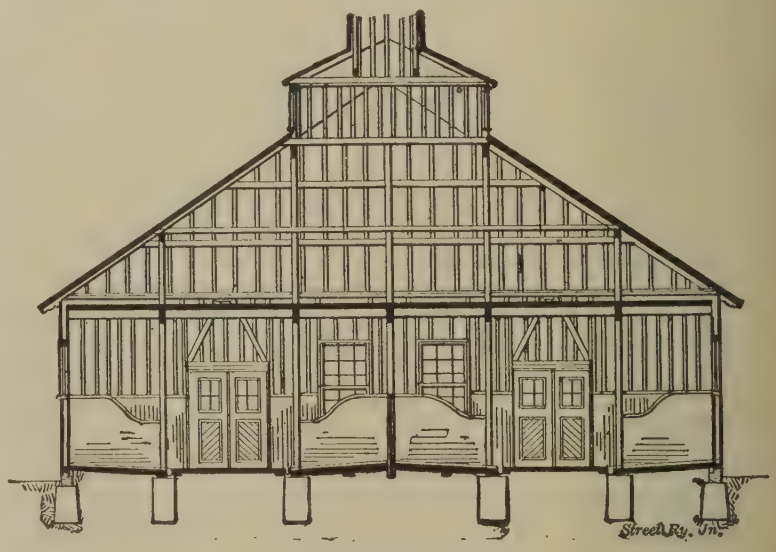


FIG. 299B.—SECTION.

ner. By means of a simple turntable, arranged as shown, the car can be readily transferred from one station to another. The paint room is separated

from the machine shop by sliding glass doors, and provided with racks and rods upon which the

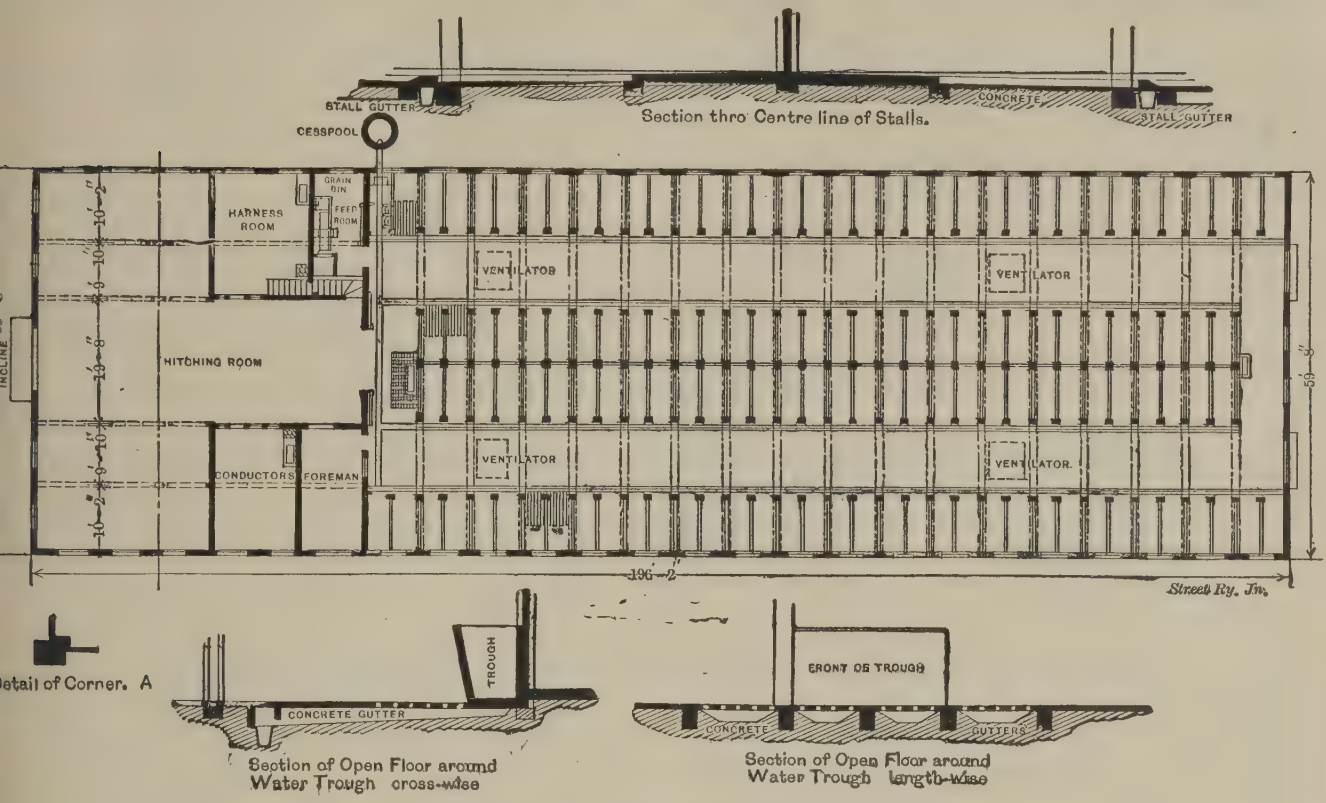


FIG. 299C.—GROUND PLAN OF FIG. 299.

these can usually be had from the stable plant. In some cases it is found to be more economical to purchase the lumber already prepared, and so avoid the necessity of providing machinery and power to operate it.

removable parts of a car can be hung while undergoing repairs. There are four tracks on which cars may be placed for repairs, on either side of

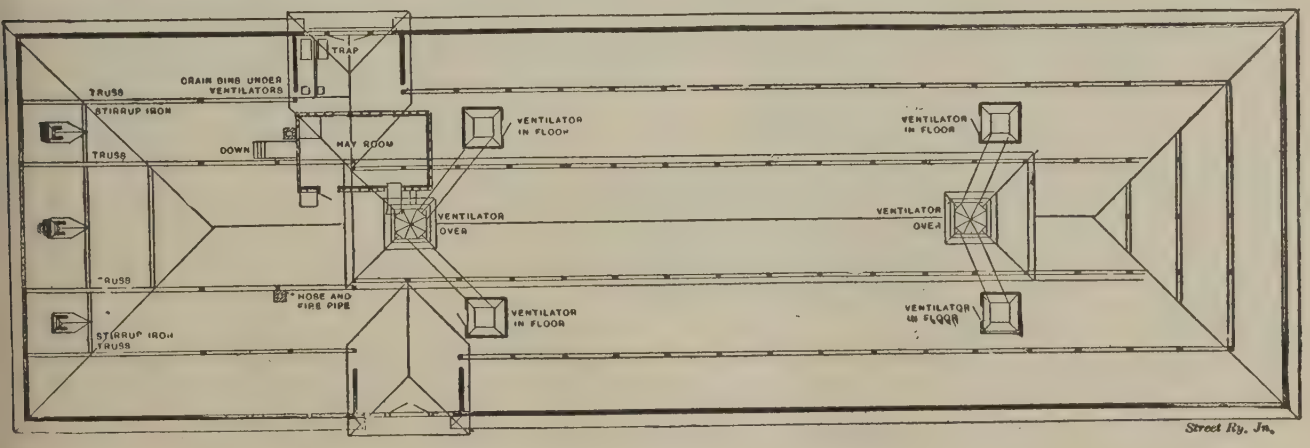


FIG. 299D.—SECOND STORY OF FIG. 299.

which are carpenters' tables and racks for supporting the tools.

In the smaller shops, however, only a small number of tools is necessary, and power for operating

The master mechanic in charge of the repair shop should be a thorough mechanic and a person well versed in car and wagon building, for it is often necessary to rebuild an entire car and to

build the carts and wagons used for hauling grain and hay, although it may not be the policy of a company to build new cars, and such a policy is not generally recommended; yet the rebuilding

FIG. 300.—CAR BARN—FRONT ELEVATION—UNION RAILROAD CO., PROVIDENCE, R. I.

often amounts to the same thing, so that it is desirable to maintain a good style, and to have the structure as durable as possible, consistent with lightness and good taste.

As a general thing, repairs should be promptly made, for, if neglected, they may require an outlay beyond the limit of good economy. In some cases the cost for a certain line of repairs may be greatly reduced by having certain parts specially strengthened. For instance; on lines where the vehicle traffic is very heavy, and the streets are often blocked, it is well to reinforce the side panels of the car with stout battens of hard wood, so that the sides will not be liable to be crushed in should they come in contact with the poles and projecting parts of drays.

A good wheel press is a convenient adjunct to a repair shop, although it is the practice of many lines to send old wheels and axles to the wheel makers who remove the wheels, replace them with new ones and return them to the company. Where the distance is not too great this is a commendable practice.

The paint shop, in connection with the repair shop, also requires at its head a man of acknowledged ability. Not only should the cars be painted and lettered so that they are attractive to the eye, but the colors should be durable and well laid. The remarks above in regard to prompt repairs will apply particularly to this department. A little paint at the proper time will often save the wood work from serious damage from water and exposure. The roof especially needs care in this direction.

Street cars should be varnished at least once a year and repainted every three or four years. The

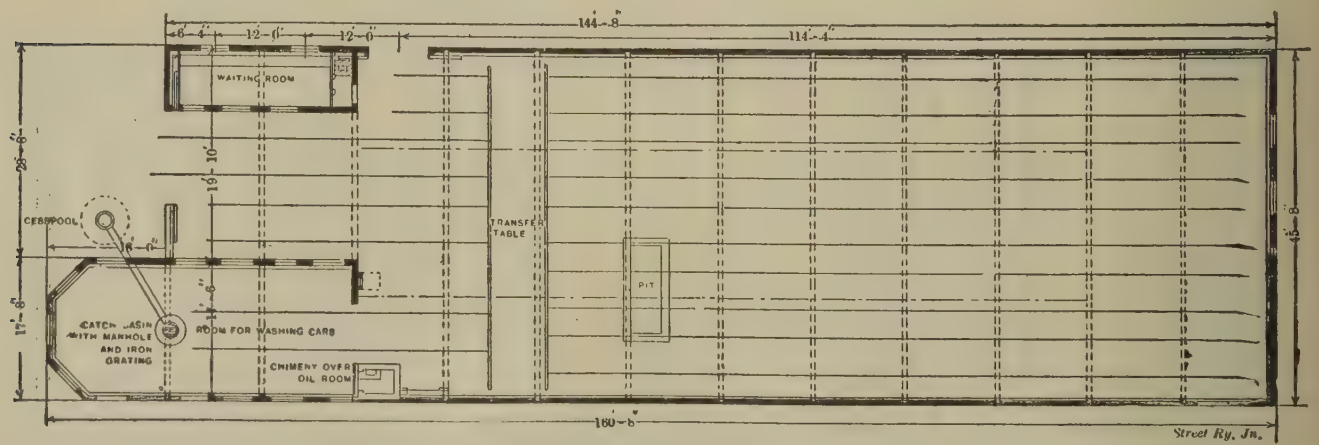


FIG. 301.—CAR BARN—FLOOR PLAN—UNION RAILROAD CO., PROVIDENCE, R. I.

room devoted to this department should be partitioned off from the repair shop proper, and is preferably located above the ground floor. Provision should also be made for heating it in cold weather.

The blacksmith department of a repair shop should be distinct from the horseshoeing department of a stable, and should be equipped for making all necessary repairs to the iron work of the cars, as well as for ironing and repairing the company's wagons, carts and drays, including the setting of tires.

FIG. 301A.—BLACKSMITH SHOP FOR TWO FORGES.

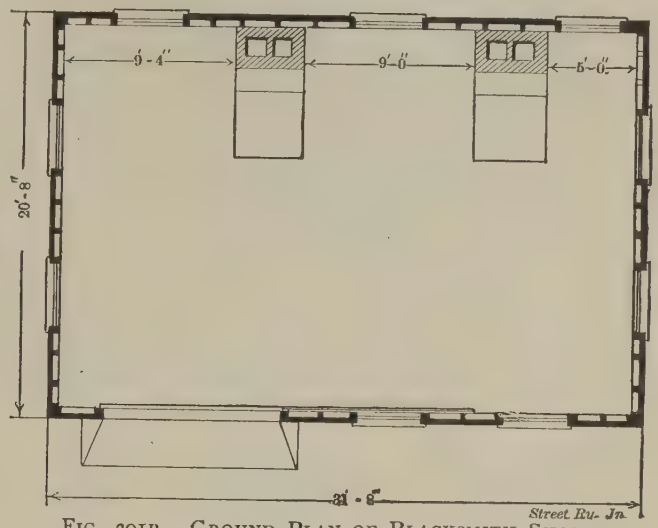


FIG. 301B.—GROUND PLAN OF BLACKSMITH SHOP.

The above suggestions should find expression in the plans of any street car stable and depot where it is desired to make the structure pleasing in design, healthful to its occupants and convenient and economical in use. See also chapter on Car Building.

MANAGEMENT.

In order that the executive officer of a street railway company may at all times be informed of the number and condition of the animals in the stables, and also in order to hold the heads of different departments personally responsible for their work, some systematic plan should be adopted by

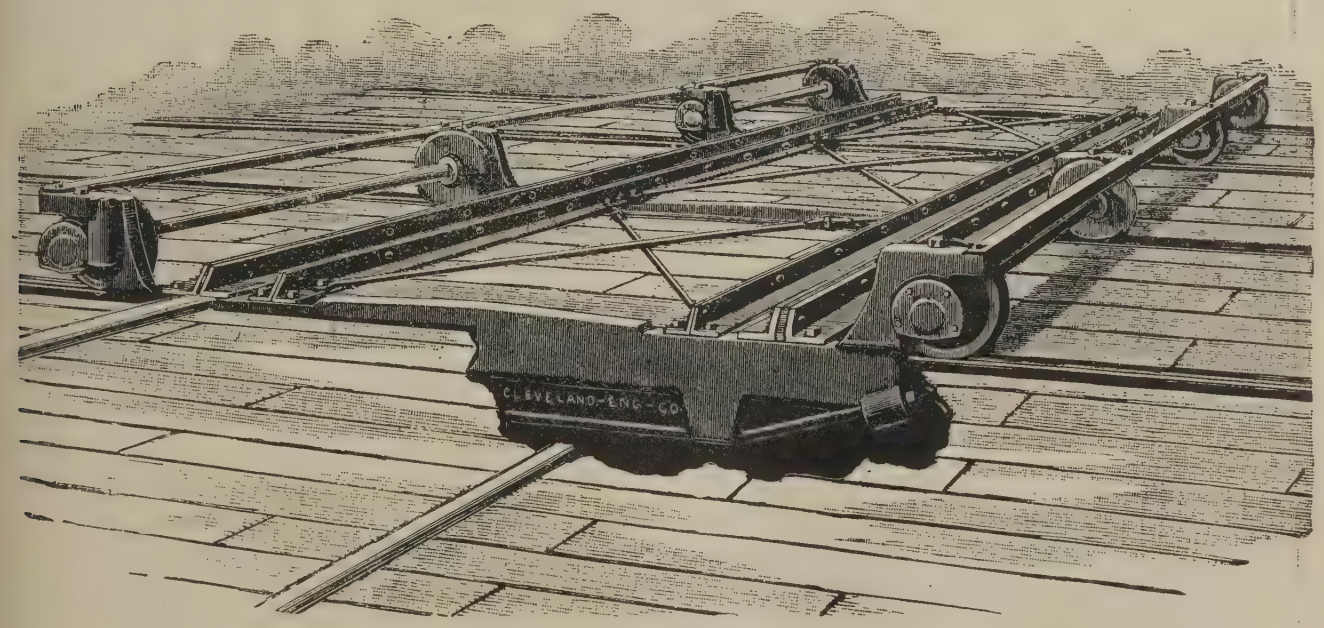


FIG. 302.—TRANSFER TABLE.

which all the subordinates (stable superintendent, veterinary, foreman and accountant) should be required to make regular daily and weekly reports, showing in detail the condition of each animal under their charge, with all changes and methods adopted in the placing, care and treatment of them.

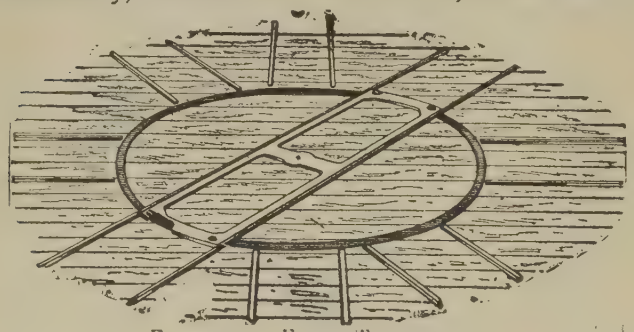


FIG. 303A.—FLOOR TURNTABLE.

These reports being duly verified, compared and checked upon the official records of the company, will furnish a daily chart showing the exact standing of the stable equipment, by which the manager will be greatly assisted in arranging the work of his road.

It should not be inferred, however, that any amount of system will relieve the manager from making frequent and thorough personal inspection of every department of the stable, but it will relieve him from numerous burdensome details.

The accompanying forms are recommended as models after which blanks may be printed for convenience in making the reports above suggested.

Form A is a blank which the stable foreman may

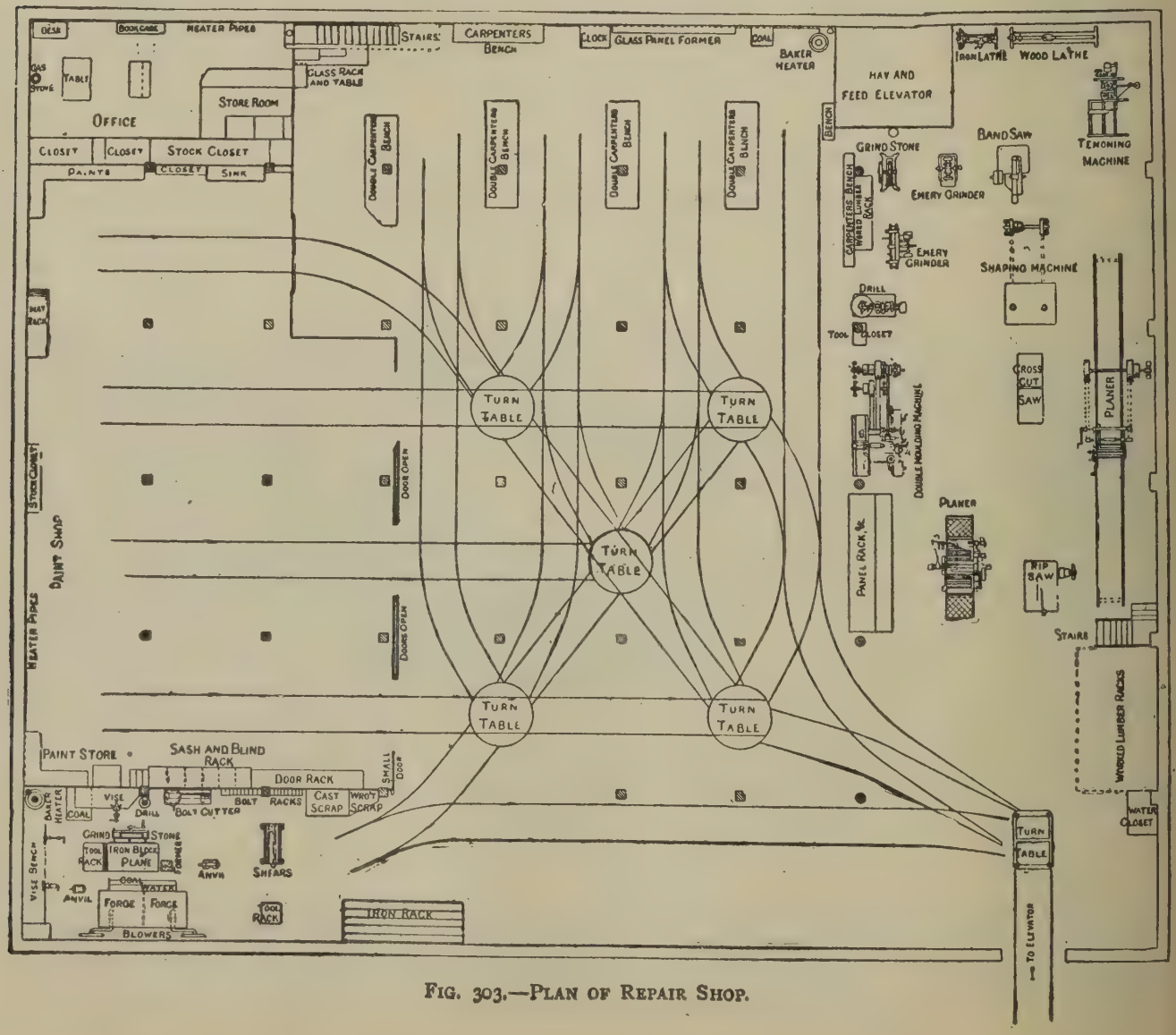


FIG. 303.—PLAN OF REPAIR SHOP.

(A)

DAILY REPORT OF STABLE FOREMAN.

BELT RAILROAD.

NEW YORK.....18

TO THE PRESIDENT:

SIR—The following is a full report for the day of all Horses received—all Horses returned—all Horses accepted and numbered—all stall transfers—all Horses sold—died—or sent to the dead boat.

Horse No.	From Stall	To Stall.	Cause.
.....	.....	.....	.....
.....	.....	.....	.....
.....	.....	.....	.....

.....STABLE FOREMAN.

(B)

BELT RAILROAD.

NEW YORK.....18

DAILY REPORT OF HORSE MILEAGE.

MR.....President.

Worked this day the following number of horses:

	Horses.	Trips.	Miles.
East Division	.....	.....	.....
West Division	.....	.....	.....
Switch	.....	.....	.....
Hills	.....	.....	.....
Carts and Trucks	.....	.....	.....

Total No. of horses..... Total miles.....

No. of horses correct, No. of miles correct.

.....Foreman. .....Starter.

Examined and verified,

.....Superintendent.

(C)

SATURDAY'S REPORT.

Weekly Return of Horses, Belt Railroad Co.

For the Week ending Saturday.....18

Number on hand this date.			
	On hand at last report.....	.....	.....
	Purchased since.....	.....	.....
.....	Number at full work.....	.....	.....
.....	" at half work.....	.....	.....
.....	" in hospital.....	.....	.....
.....	" for sale.....	.....	.....
.....	"	.....	.....
.....	"	.....	.....
.....	" Pasture	.....	.....
.....	Returned during past week...	.....	.....
.....	Sold " " ...	.....	.....
.....	Died " " ...	.....	.....
.....	Total on hand.....18	.....	.....

.....Foreman of Stables.

Superintendent.....

REMARKS.

.....

use for making a daily report to the president. Form B is to be used by the stable foreman and starter in making a report to the superintendent,

(D)

SUPERINTENDENT'S WEEKLY REPORT.

For week ending Saturday.....18

		Corresponding Week Previous Year.
Cars run { East Division.....	.....	.....
Cars run { West Division.....	.....	.....
Cars run { One-Horse	.....	.....
	.....	.....
Cars rebuilt and painted.....	.....	.....
" slightly repaired.....	.....	.....
" with new wheels and brasses..	.....	.....
	.....	.....
No. of men in car and paint shop..	.....	.....
Cars broken on road.....	.....	.....
	.....	.....
Horses—Whole No.....	.....	.....
Full work.....	.....	.....
Half work.....	.....	.....
Hospital.....	.....	.....
For sale.....	.....	.....
Diseases—No.	.....	.....
.....	.....	.....
.....	.....	.....
.....	.....	.....
Lame, { Hip	.....	.....
Lame, { Shoulder	.....	.....
Lame, { Foot.....	.....	.....
	.....	.....
Conductors—Regular.....	.....	.....
" Extra.....	.....	.....
Drivers—Regular	.....	.....
" Extra	.....	.....

SUPPLIES.

Used during week, of Hay, ...	On hand, ...	
" " Straw, ...	"	
" " Corn, ...	"	
" " Oats, ...	"	
" " Bran, ...	"	
" " Salt, ...	"	
Proportion of feeding		
Pounds of hay and meal per horse, ...		

Remarks .....

Required during week .....

.....

.....Superintendent.

which, being approved by him, is transmitted to the accountant, who copies it upon the books, and from it, once a month, computes and reports the daily

stable and road average of miles travelled by the animals.

Form C is for the weekly Saturday evening report which the stable foreman and superintendent may be required to make, and form D is for a second weekly report to be required of the superintendent on Monday.

On the last Saturday night of each month the superintendent may be required to count the animals in the stable to see that the total balances with the accountant's books before the reports are filed for entry on the year's accounts.

A mechanical record is also sometimes made by the chief officer, which is changed each day to correspond with the daily reports. Such a record may be made by having a small table divided up to represent the stalls, which may be numbered to correspond with the stalls in the stable, while small cubical blocks may be used to represent the horses. The blocks, being of a different color on each face, may be so placed as to indicate the condition of the animals (Fig. 304).

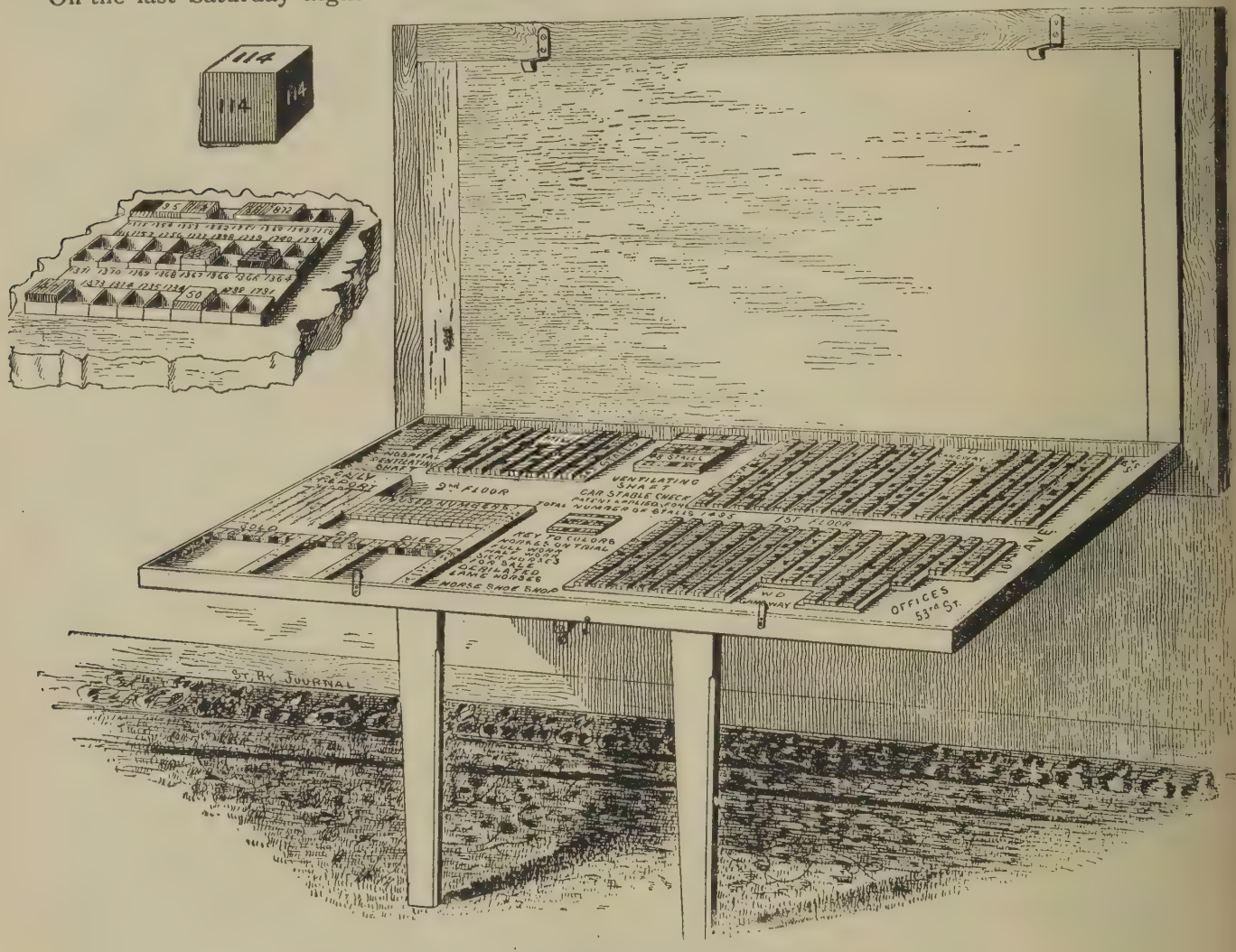


Fig. 304.—Mechanical Stable Check.

DISEASES AND TREATMENT.

Although there has been a long felt need of a work treating especially on the diseases of street car horses, which could be recommended to managers as a safe and scientific guide in the treatment of all forms of disease to which this class of animals are subject, it is manifestly beyond the scope of this volume to cover this field, and there is little that can be said on the subject except to recommend to the intelligent manager the use of such veterinary works as treat the whole subject in language of a more or less popular style.

A regular veterinary doctor should be employed in all cases where the number of animals in the stable will warrant the outlay. Where this is not the case, the services of a resident veterinarian should be retained. There will be, however, too many cases in which the veterinarian cannot be called in time for success, if at all; hence, the manager or stable foreman who knows or has the means of learning the nature of the disease and the proper treatment may be able to save an animal when otherwise it would die.

The manager should not only be informed in order that he may in special cases treat his ailing animals or allow them to suffer without treatment, but he should have at his command the published advice of veterinarians eminent in their profession, in order that he may detect and prevent the absurd and often barbarous methods of treatment which an ignorant foreman or even a veterinarian who follows traditional rather than scientific methods, may at times introduce. Not only is it suggested that the manager should study works treating on this subject for the reasons above mentioned, but also that he may instruct his stablemen and be able to recommend to them and to his veterinary the use of such medical literature as can be readily comprehended by an ordinary mind.

Scientific medicine need no longer remain a sealed book to the stable employes as a class, for there are works that present the matter in language so simple that anyone may learn to practise humane and scientific treatment in the diseases which afflict this most faithful and patient servant of man, "the street car horse."

First in the short list of works treating on the diseases of the horse which are recommended, may be placed, the "Special Report on Diseases of the Horse," issued by the United States Department of Agriculture, which may be had on application to the Secretary of Agriculture. Although this work is issued for distribution to farmers it will be found exceedingly valuable to all who have the care of horses.

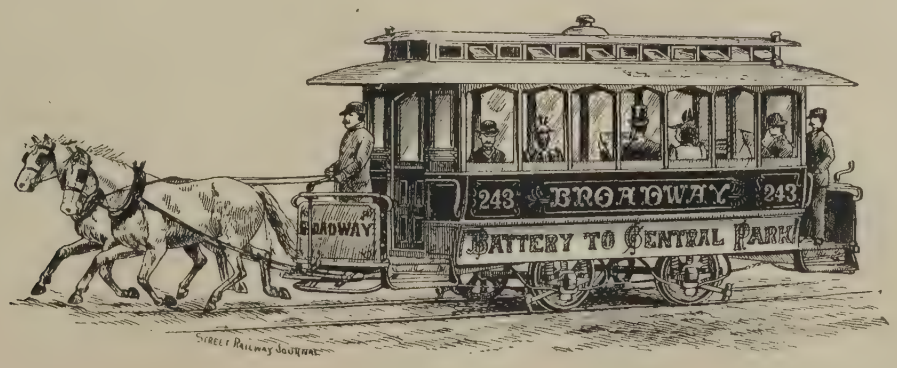
"Russell on Scientific Horseshoeing," a work previously mentioned, is placed second and is recommended, not only because it treats of horseshoeing and diseases of the foot, but also contains a chapter of useful prescriptions and remedies pertaining to the treatment of most of the diseases to which a street car horse is liable.

Third on the list is placed, "The Anatomy of the Horse," by J. M. Fadyean. Although this work was specially designed for the use of veterinary students, it will prove exceedingly valuable to a veterinary practitioner and useful to the managers of horse railways.

Should one wish to continue his studies farther and exhaust the subject, he will find that "Youatt's History, Treatment and Diseases of the Horse" fully covers the field.

For such lines as employ mule power, "Riley on the Mule" will be found to be an exceedingly interesting work to study.

Should it be found necessary to cultivate a kindly disposition among stable employes relative to their treatment of the animals under their charge, "Black Beauty" is recommended as just the work for this purpose.



CHAPTER IV.

STEAM, AIR AND GAS MOTORS.

Before the advent of cable and electric traction, in fact, in the early history of street railways, considable attention was given to the development of some means of mechanical traction. This effort grew out of an idea then, and still, prominent in the minds of many street railway men and others, that "the employment of horses on tramways is a misfit and a barbarism," and not only a misfit but an expensive means also.

Naturally enough, following steam railway experience, the energies of engineers were first directed in the line of modifying the locomotive and adapting it to the requirements of street railway service, and although they have succeeded, after long study and patient industry, in producing "a noiseless, vaporless, smokeless and handy machine," one that can be operated more cheaply per car mile than animal power, they have never succeeded in overcoming the prejudice that exists everywhere against the employment of independent steam motors on city streets.

The popular rivals of the steam motor (cable and electricity) have, however, done much to overcome prejudice and allay the fears of people in regard to the frightening of horses and liability to accident, as there are now, since the advent of safety boilers, no accidents peculiar to the use of steam that are not shared in or exceeded by the new comers. But in this connection it is gratifying to note that long service has proved that all classes of mechanically propelled cars are safer in operation than cars drawn by horses even though they are run at a higher speed. The theory is that people are not so apt to take their chances in crossing a street in front of mechanically propelled cars as they are with horse cars.

Not only has the rival, electricity, assisted in overcoming prejudice, but it has demonstrated the possibility of climbing steep grades and combating with snow, and overcoming difficulties that had, heretofore, impaired the success of steam motors.

From the above it will be seen that the steam motor, instead of retiring from the field, vanquished, as many predicted, can be improved along the lines indicated, and still find a large and inviting field of operation for which no other means of traction is so well adapted. We refer to suburban roads, hotel and excursion roads in places where the season is short and the business irregular, and to temporary extensions of electric or cable roads where the expense of these systems and the amount of business offered would not justify their use.

The following conditions, requisite to the successful use of steam on street railways, are quoted from reliable authority:

"1st. A tramway engine must be capable of coming to a dead stop within a short distance and starting again with the greatest facility.

"2d. It must be able to run around very sharp curves.

"3d. It must have a very wide range of power, adapted for taking very variable loads and ascending the steepest gradients.

"4th. Perfect safety must be secured both for passengers and for the general public.

"5th. The dimensions must be moderate, particularly the width, and there must be nothing likely to cause horses to take fright.

"The secondary conditions which it is desirable to aim at fulfilling, may be stated as follows:

"1st. The engines should emit no steam or smoke, no water and no ashes or cinders.

"2d. They should contain no liquid or gas at high temperature, which might, in cases of breakdown, collision or overturning of the vehicles, scald or otherwise injure the passengers or others.

"3d. They should not require more attendants an the horse cars.

"4th. They should be capable of running backards, which cannot always be done on tramways, it is desirable as a provision against accidents.

"5th. The working parts must be accessible and ept free from dust · all joints and rubbing surces should be easily and thoroughly lubricated."

To these should be added that the rails should heavy and of the most approved pattern, and e road bed conructed in the ost substantial anner.

The motor should adapted in wer, weight on e driving wheels d speed of runng to the grades, affic and other atures of the line n which it is erated.

While the above nditions are imrtant to the sucssful working of steam motor, inlligent management and an earnest, vigilant dere on the part of all in charge to keep down the xpenses of running and repairs are of equal ecessity; to secure this the motors should be run y picked men, who will obey orders strictly; ney should be inspected daily to seek out all eeded adjustments and repairs, which should be ade at once; and the whole motive power should e in charge of a competent superintendent, whose hole interest it is to reduce the cost of successful peration to the lowest possible limit.

The most important factor, after the above, for he successful operation of steam motors is a properly equipped and properly manned repair shop. Many railway managers seem to think that a motor hould run forever without any fixing beyond that furnished by the profanity of the engineer, but this is a mistake, a machine may run fifteen months without repairs, and it may not run fifteen minutes. It is just as absurd to attempt to operate a mechanically propelled line without a machine shop and proper housing for the motors as it would be to open a horse line without first providing a stable for the animals.

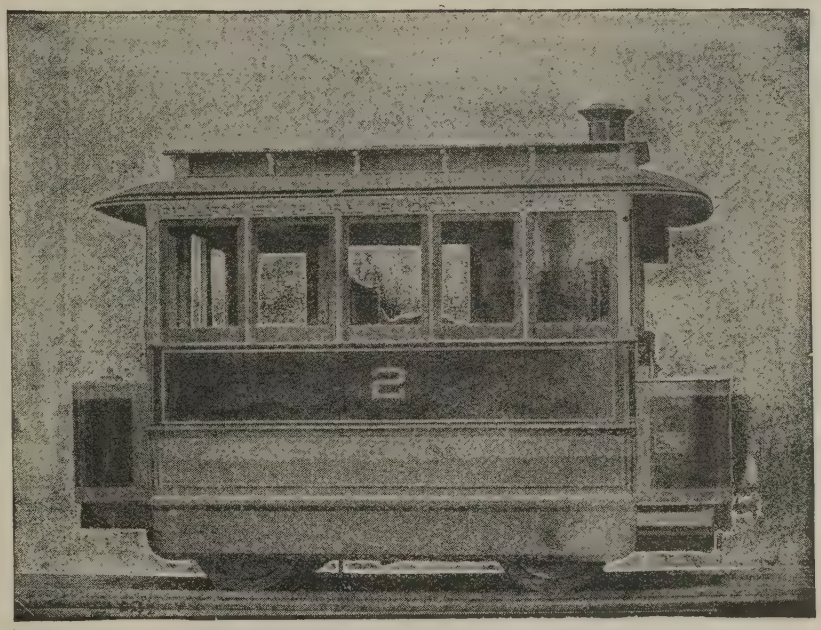


FIG. 304.—BALDWIN STEAM MOTOR.

Among the early types of steam motors the power was transmitted to the axles by means of gearing, but this proved to be a very unsatisfactory arrangement on account of the loss of power by friction, the noise in operation and expense from wear and tear. The use of crank axles has also been very generally discarded by the leading manufacturers in this country, on account of their liability to break, but they are still in favor with foreign builders. The essential principle of construction conforms closely to regular locomotive practice, but the objectionable features of the latter are eliminated as far as possible. A housing covers the entire machine, concealing the motion of the machinery and giving to the motor much of the appearance of an ordinary horse car. The locomotive type of boiler designed to work under a steam pressure of 130 lbs. is usually adopted. The machinery usually consists of two outside horizontal cylinders, with the connecting rods taking hold of wrist pins on the outside of the driving wheels which are usually steel tired and coupled by side rods. The eccentrics, links and valve motion are modeled after locomotive practice. The wearing parts are made of steel, case hardened iron or bronze metal,

and are constructed with special reference to durability.

FIG. 305.—BALDWIN PONY TRUCK MOTOR.

Steam and lever brakes are provided, and each machine is supplied with all necessary tools.

Coal or oil may be used as fuel; to avoid smoke the use of anthracite coal or coke is recommended. On ordinary grades it will require from eight to twelve pounds of coal per mile.

Fig. 304 illustrates a type of motor designed to take the place of horses in city streets, and occupy no more room, while capable of hauling from one to four cars. This type of steam motor and also that shown in Figs. 305 and 306, are manufactured by the Baldwin Locomotive Works of Philadelphia, Pa. In the first the entire weight is carried on four driving wheels, which are coupled so that the motor is well adapted for service on steep grades. The tank is placed on the engine frame back of the cab, and is cut in the middle to allow entrance to the cab at the back. Hinged apron boards hide the side rods when in their lowest position. These motors are made in four sizes having cylinders from 8 ins. × 12 ins. up to 11 ins. × 16 ins. The minimum diameter of driving wheels is thirty-

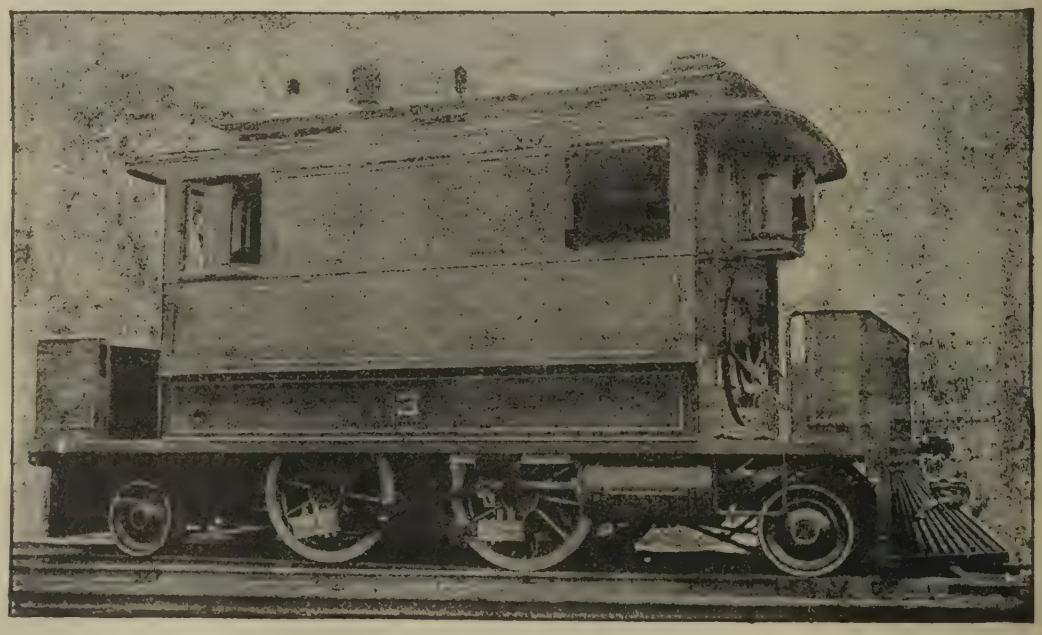


FIG. 306.—BALDWIN "DOUBLE ENDER" MOTOR.

one inches, wheel base five and a half feet, total weight 13,000 lbs., and load on level track 250 long tons; weight of largest size 26,000 lbs., and load

500 long tons. Fig. 307 is also a type of four wheel rear tank motor, with side flaps and pilot, built by H. K. Porter & Co., Pittsburgh, Pa., These are built in five sizes, the smallest having cylinders 6 ins. × 10

FIG. 307.—PORTER FOUR-WHEEL REAR TRUCK MOTOR.

ins., diameter of wheels twenty-three inches, wheel base four feet, length over all fifteen feet, weight 14,000 lbs., capacity of tank 125 gals., hauling capacity 250 short tons.

Figs. 308 and 309 are two types of saddle tank

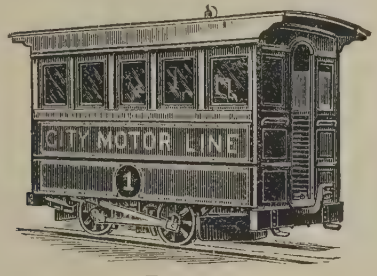


FIG. 308.

motors built by the same firm, one with and the other without boards, pilots and side flaps.

Another type of motor and one that is used more extensively than any other for street railway purposes, is illustrated in Figs. 305, 310 and 311. The

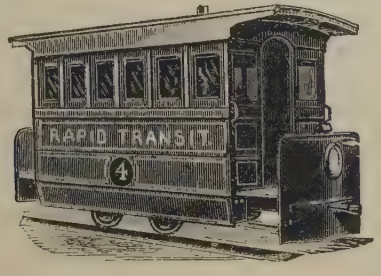


FIG. 309.

last two are also built by H. K. Porter & Co. These are designed for a higher rate of speed, and a pony or rear truck is added to obviate a tendency toward a galloping motion to which four wheel motors are subject when running at a high speed. The pony truck has a swinging bolster and radius bar, so that the motor is enabled to pass curves of short radius very easily.

The pattern shown in Fig. 305 is built in seven sizes, the cylinders ranging from 8 ins. × 12 ins. to

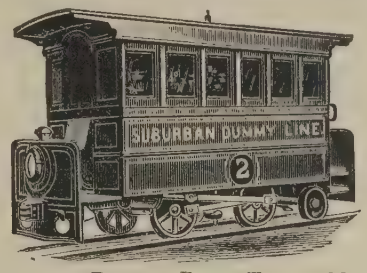


FIG. 310.—PORTER PONY TRUCK MOTOR.

14 ins. × 20 ins., the first having thirty-one inch driving wheels, driver wheel base four feet, total wheel base seven and a half feet, weight in working order 19,000 lbs., weight on drivers 15,000, load on level 290 long tons. Fig. 310 is built in four sizes,

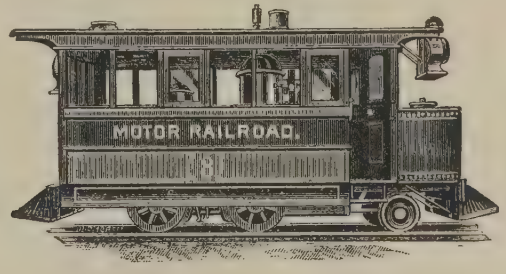


FIG. 311.—PORTER PONY TRUCK MOTOR.

minimum size of cylinder 7 ins. × 12 ins., diameter of driving wheels twenty-eight inches, truck wheels sixteen inches, rigid wheel base four feet eight inches, total wheel base eight feet five inches, length over all fifteen feet six inches, height nine

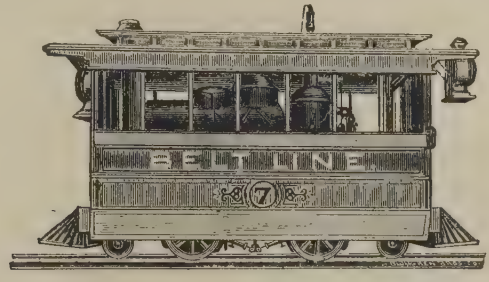


FIG 312.—PORTER "DOUBLE ENDER" MOTOR.

feet five inches, total weight 19,000 lbs., weight on drivers 14,000 lbs.; weight on two wheel radial bar truck 5,000 lbs., capacity of saddle tank 200 gals.

Figs. 306 and 312 are known as the "double ender" type, and are the most suitable designs for running both ways at high speed. Each pony

truck of the first has swinging bolster and radius bar, one truck being centre bearing the other side bearing, giving the motor lateral stability. These motors will run smoothly over uneven track as all the wheels will find a bearing.

Fig. 313 is a longitudinal section of a foreign tramway locomotive, which has established a reputation abroad for doing good and economical work. Fig. 314 is an end view, and Fig. 315 plan below

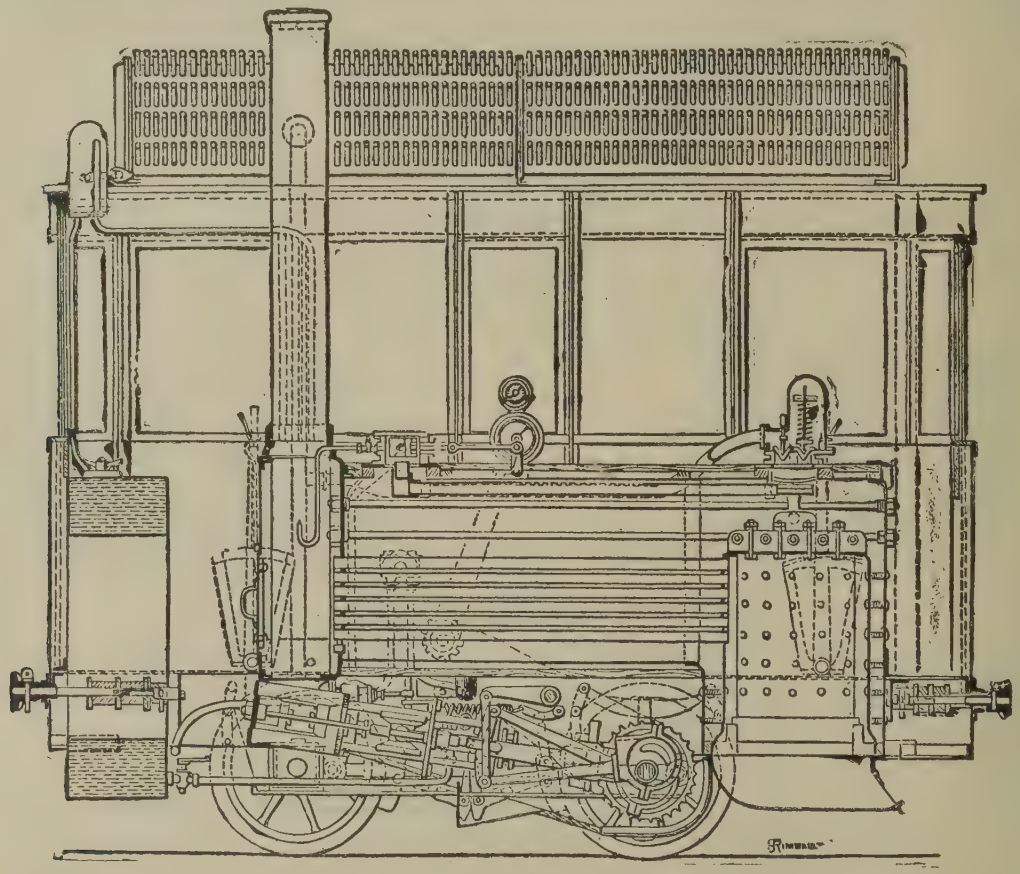


FIG. 313.—THE MERRYWEATHER ENGINE.

the foot plate, which plainly illustrates the difference between home and foreign practice. The plates and description are copied from the very excellent English work by D. K. Clark, entitled "Tramways."

"The cylinders are placed inside the framing, and are joined together at the middle, where they form the valve chest, whilst a saddle is placed on each half for the purpose of supporting the boiler at the smoke box. The grate bars are of steel, the crosshead is of cast steel and the crosshead slippers are of cast iron, having large wearing surfaces. The guide bars are supported by a cross plate which they considerably overhang in the direction of the fire box. The guides for the valve spindles are carried by the same plate.

"The link motion is of the ordinary shifting link type. The eccentrics and hoops are of cast iron. The coupling rods are made with solid ends, having phosphor bronze bushings. The boiler is of the usual locomotive type, of Lowmoor iron throughout, doubly riveted in the longitudinal seams. The feed tank, holding 100 gals., is placed in front of the smoke box. A fender plate is fixed at each end of the engine to remove obstructions, and to obviate any chance of running over any person. The whole of the work is enclosed in a cab or casing of sheet iron on angle iron framing, twelve feet in length, six feet four inches in width and about eight and a half feet above the rails.

"The condenser, placed above the roof, consists of four horizontal layers, slightly arched, of thin copper tubes, laid transversely across the roof. The tubes are one inch in diameter outside, one fifty-

fifth of an inch in thickness and are each six feet in length. There are sixty tubes in each layer, or 240

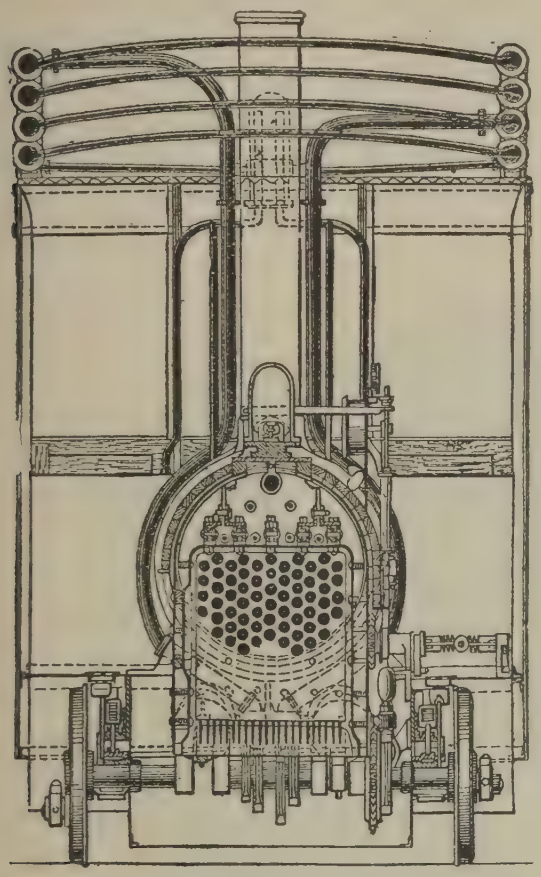


Fig. 314.

tubes in the four layers, coated with brown varnish to augment their radiating power. They are brazed at the ends into three inch longitudinal pipes, three inches in diameter outside, four on each side, eleven feet long. The exhaust steam is discharged by two copper pipes, one to each side into the uppermost longitudinal pipe, whence it circulates through the transverse tubes. The condensation water and the remaining vapor are conducted into a separator vessel at the front, whence the water runs down to the feed water tank, and the vapor passes away into the smoke box, where it is mixed with and disappears with the products of combustion. So efficient is the condenser that the engine can be worked all day with one charge of the feed water tanks. This tank holds only 100 gals., and the quantity consumed as uncondensed steam or otherwise does not exceed fifty gallons for the day.

"Steam levers and reversing levers are fitted in duplicate, one of each at each end of the engine, so that the driver may take his place at the leading end, whichever end goes first. There is a speed indicator and a bell governor for shutting off steam when the allowed speed—ten miles an hour—is reached.

"The fire box is one foot ten inches long by two feet wide inside, and is two feet one and a half inches high above the grate. The barrel of the boiler is two feet four inches in diameter inside. There are sixty-four flue tubes, one and three-fourths inches in diameter outside, and five feet in length. The grate area is 3.8 sq. ft. and the heating surface is 169.2 sq. ft.

"The working pressure of steam in the boiler is 140 lbs. per square inch. The cylinders are six and a half inches in diameter with a stroke of ten inches. The wheels are twenty-six inches in diameter, placed at four and a half feet centres. The whole of the machinery is encased from below.

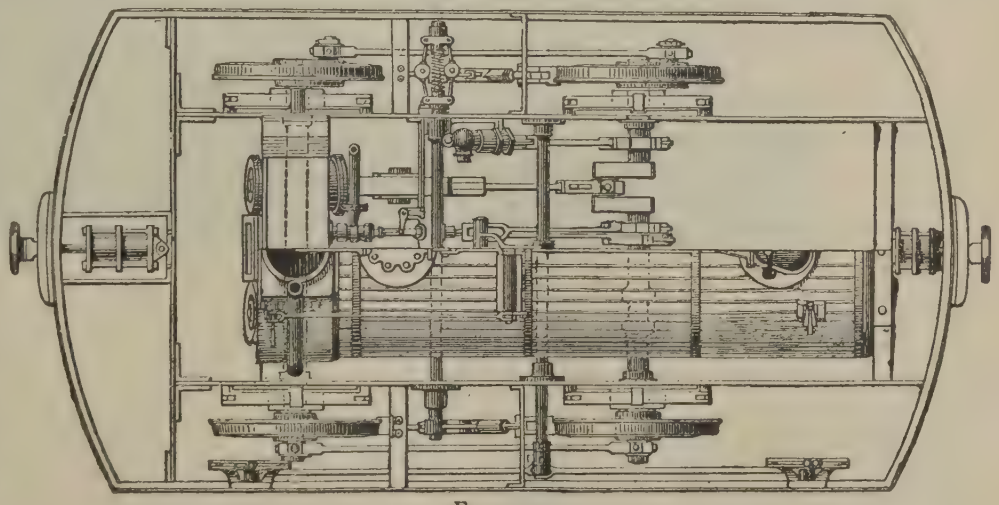


Fig. 315.

The weight of the engine, empty, is six tons; and in working order with water and fuel, seven tons. It consumes 6.911 lbs of coal per mile."

Another foreign type of steam motor, which has recently been introduced in this country is illustrated in Fig. 316.

The compound cylinders are placed below the floor and are coupled direct to the connected drivers. The exhaust passes to the series of condenser pipes which are located on the roof.

cars, we gain the following items of expense for operating:

Average number of miles run per day, 100; average grade, five per cent.; fuel consumption in pounds per mile of anthracite coal, 15.6 lbs., costing 4.1 cts.; coke, fifteen pounds, costing 3.33 cts.; soft coal, 28.3 lbs. costing 4.7 cts. Total cost of

Fig. 316.—Steam Tramway Locomotive.

The body of the motor is twelve feet long, seven feet eight inches wide, and nine feet high, and, complete, weighs about seven tons. The drivers are thoroughly housed in, and access is had to the journals by means of swing doors as shown.

From the published reports of the operation of twenty-nine steam motors on as many different lines in this country, each hauling from one to four

operating per mile run, including wages and repairs, 11.04 cts.

Fig. 317, illustrates the general design of a steam car, having the boiler located in the front end separated from the passenger compartment. The cylinders are under the platform outside the car body, so that no heat or steam can be communicated from them to the passenger department. A com-

bined car and motor has the merit of taking up the least possible room, but is objectionable on account of the position of the machinery, it being unhandy for making repairs, and because an upright boiler is required and because the motion of the car is apt to be too rough, and the passengers are annoyed by the vibratory motion of the engine and the heat of the boiler and smell of the oil. Some of these objections may be overcome by careful designing, but this type, although desirable for many reasons, has not become as popular for steam practice as the independent motor.

from the engines to the car. The tank is placed under the seats and the machinery is perfectly protected from the dust by a suitable casing. On roads with many heavy grades this motor consumes seven pounds of anthracite coal per mile of travel.

Some types of combination steam cars which are doing excellent service on several foreign lines are illustrated in Figs. 320 and 321. These cars are operated by the Rowan system of which many styles of bodies are constructed. Fig. 320 has an open platform and closed rear part, without class

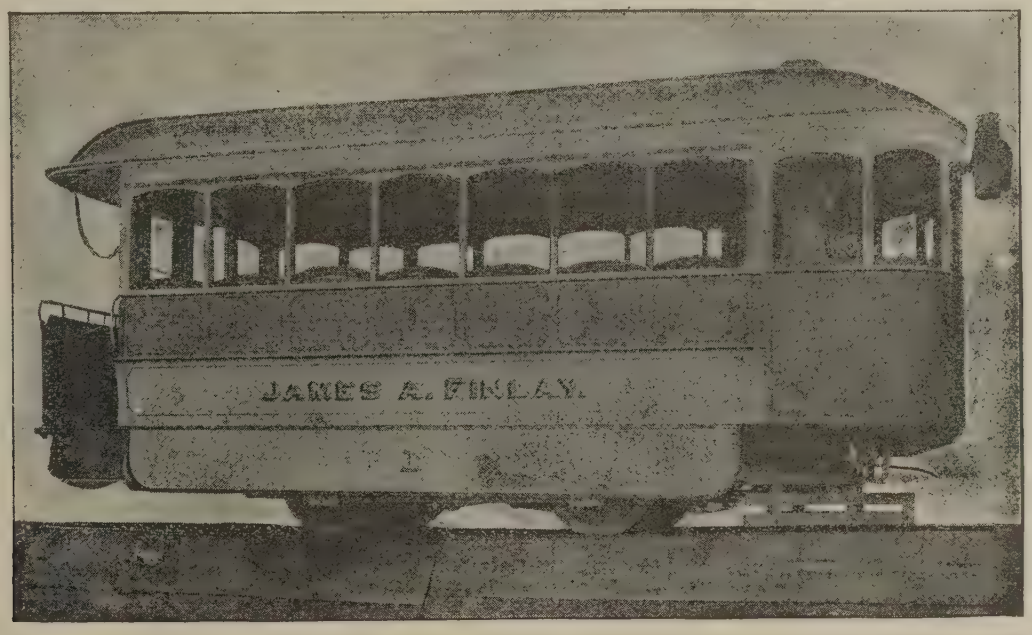


FIG. 317.—BALDWIN STEAM CAR.

Fig. 318 illustrates the machinery and framework of a steam car before the car body is placed in position.

Fig. 319 is an illustration of the machinery and truck of another type of combined car and one that has met with considerable favor in operation. The forward end of the engine is suspended by a link. The engine frame is attached to the driving axle so that the working strain falls on the driving axle alone. Engine and drivers are one piece of machinery, and it will be noted that the cylinders are between the wheels, close together and connected directly with the driving shaft. By this arrangement no rolling motion is communicated

distinction, and is a style employed on some of the lines in the vicinity of Paris.

Fig. 321 is designed for suburban service, and has a compartment for baggage, and two class apartments. In the latest designs of engines for this system two vertical boilers are employed, which are usually connected above the water line; some, however, have two smoke stacks. Coke is burned for fuel, and in operation the engines are smokeless and noiseless. The cylinders are placed horizontally between the wheels to which they are connected in some cases by intermediate gear; in others they are coupled direct. The water tank has a capacity for five hours' run. The exhaust is

led to the condenser which is located on the roof, and has 1,120 ft. of pipe surface.

The motion of these cars is said to be very easy and free from vibration, owing to the method of spring hanging and to the design of the bogie truck and the method by which it is connected with the frame, also to the rear radial pony truck.

The cars that are designed to seat fifty people have a total length of fifty and a half feet, and are seven feet wide; they weigh, in working order, 19,800 lbs., of which 17,600 lbs are available for adhesion. A forty H P engine burns from five to seven pounds of fuel per mile run, and the tractive effort is about 2,640 lbs

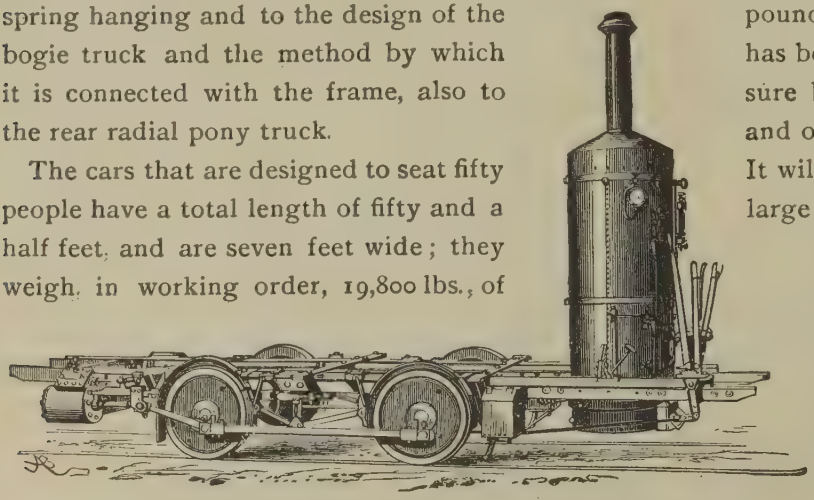


FIG 318.—TRUCK AND ENGINE OF STEAM CAR.

Besides the above types, steam cars are made with double trucks (eight wheels), some having engines attached to each truck, others with only one engine. Double and triple compound engines are also used on several types of steam cars. The different patterns of combined cars are almost endless so that it is impossible to illustrate all. The above cuts will serve to give a general idea of what has been accomplished in this direction.

STORED STEAM

or hot water motors have received a great deal of attention from inventors at home and abroad, and many people are still working along this line with a commendable persistency, notwithstanding that the way is thickly strewn with the evidences of defeat.

This type of motor is constructed on the principle of "spontaneous evaporation;" that is, a body of water being heated under pressure generates steam when the pressure falls and the temperature and pressure correspond, the same as in an ordinary boiler. Water heated to 445 degs. F. has a corresponding pressure of 400 lbs. per square inch; cooled to 281 deg. F. the pressure is fifty pounds, while more than one-fifth of the water has been converted into steam. Let the pressure be reduced from 200 lbs. to fifty pounds and one-ninth of the water will be evaporated. It will be seen that such boilers must carry a large quantity of water as compared with furnace boilers, as not more than twenty per cent. can be utilized as steam.

There are three methods of working these motors; in the first, the boiler is partly filled with water and then charged with steam from a stationary boiler; in the second, a furnace is provided which is fired up, and after the water is heated to the required temperature the draft and chimney are hermetically sealed; in the third, the boiler is charged, as in the first case, and reinforced by a quantity of heated metal.

The following are some of the claims made for these motors: The steam, being generated in a stationary boiler with cheap coal, is produced at a low cost; no fuel being carried there is a reduction of dead weight; a very high pressure of steam may be used; only one attendant is required. The reservoirs for storing the heated water are sometimes placed under the floor of the car, under the seats on the roof or in a separate compartment. The cylinders are about the same as those described for "live steam" motors, and are made to work upon an intermediate crank shaft, or may be coupled directly to the drivers.

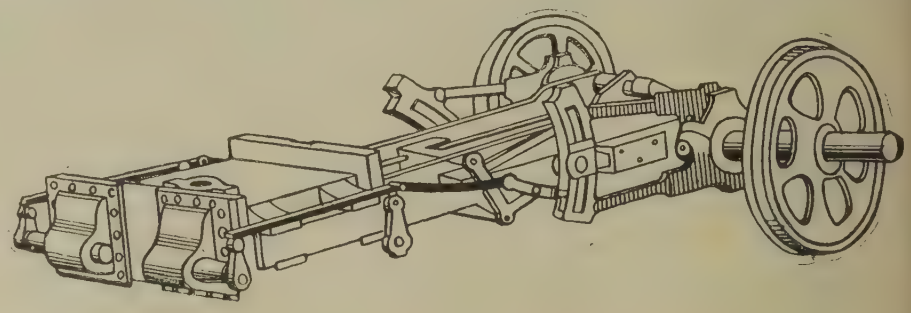


FIG. 319.—THE RANSOM STEAMER.

A motor of this class is illustrated in Fig 322. Two cylindrical reservoirs located in a compartment crossways of the car, are charged with water at a temperature of 400 degs. Within each of these are two small cylinders eight or ten inches in diameter, which are provided with a rack or cradle on which red hot metal balls, six inches in diameter, are placed. On each reservoir is a dome flanked on each side by smaller domes, which are vertical flue condensers, the flues being surrounded by a spiral pipe.

Vent pipes from each of the enclosed cylinders pass through the steam domes and out at the roof, having air valves. The heads or doors of the enclosed cylinders are also provided with vent valves.

The reservoirs being charged and the red hot balls in place, the vents are closed and the air surrounding the balls becomes dead air, so to speak, and a good non-conductor, causing the balls to retain their heat.

The car is run for a time by the original charge of hot water until the gauge indicates too low a pressure, when the vents communicating with the enclosed cylinders are opened, a circulation of air about the hot balls is established, so that their heat is imparted to the water, quickly raising the pressure; the vents are then closed, the air becoming dead as before, and opened when necessary.

Two ten H. P. vertical engines located on the front platform, as shown, connect with a crank shaft beneath the platform, on which is an intermediate gear with a broad concave face, meshing into a second gear on the front axle; the intermediate gear being curved concentric to the axis, about which the truck swivels, allows of the shorter curves being passed without disengaging the gears.

The motor is operated with three levers, and the exhaust passes to the condensers, from which the water is returned to the reservoirs

One of the latest motors of this class, is so designed that a small quantity of water is delivered direct to the cylinders. The car is provided with four storage cylinders located in pairs under the body in front and rear of the trucks. These cylinders are about a foot in diameter and are tested up to a very high pressure. These are stored with water at about 400 degs. temperature sufficient to operate fifteen H. P. hours, and they are expected to make twenty miles before recharging.

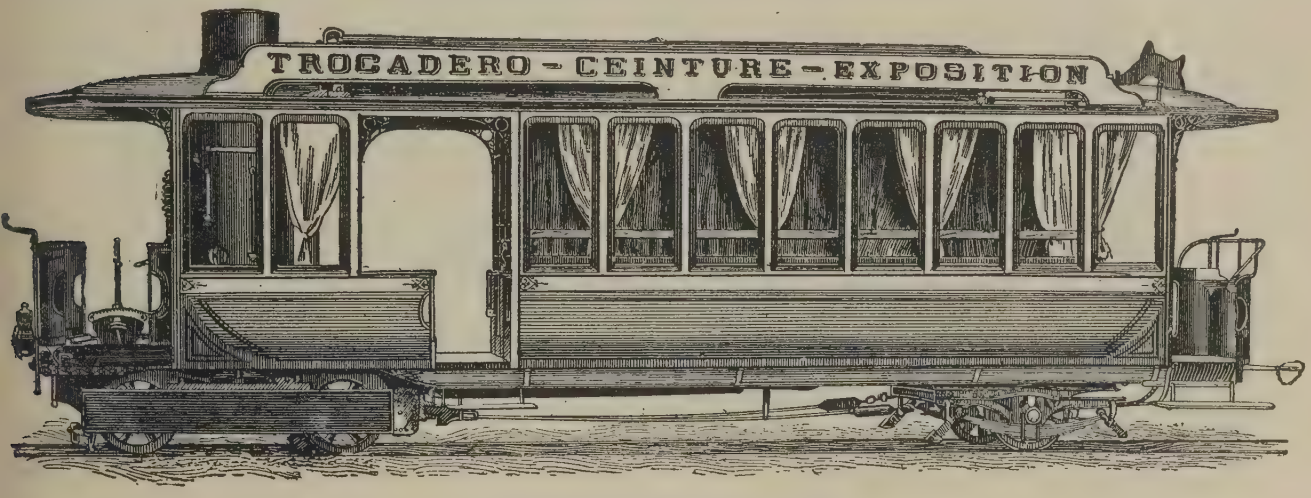


FIG. 320.—ROWAN'S STEAM CAR.

The engine consists of four single stroke cylinders, 8 ins. × 16 ins., placed side by side under the car body between the axles, and connected by cranks at different angles with the main shaft which in turn conveys power by single reduction gear to the rear axle. The main shaft is connected by discs and connecting rod to a second shaft which in turn is geared in the same manner to the front axle. The valves are operated by two eccentrics. About two cubic inches of water are delivered to each cylinder, the valves being cut off at a quarter of an inch.

The water, it is claimed, flashes into steam and expands to nearly atmospheric pressure before the stroke is completed. The exhaust is led into a system of parallel pipes about two inches in diameter, placed upon the roof of the car from which it escapes without producing any noise or vapor. The power equipment adds about a ton and a half weight to the ordinary car.

COMPRESSED AIR MOTORS

have allured many inventors and engineers into their development, but in almost every case the subject has been more fascinating than practical. Air motors are usually constructed with storage tanks or reservoirs which are charged at a central station with a supply of air previously compressed by steam power and worked expansively in small engines on the car and from which the force is transmitted to the drivers in the same manner as on steam motors.

Sometimes, however, the supply is conducted along the line of the road in pipes, from which the reservoirs are charged at frequent intervals, the motor being halted for the purpose. Attempts have also been made to draw a continuous supply automatically from the main by means of standpipes and valves.

To the uninitiated it would seem to be a very simple and practical matter to compress air, store it in tanks on board a car and expand it in a propelling engine so that the efficiency would be equal to the generating force, less the losses by friction and clearance. But there are physical difficulties connected with the working of air expansively which entail a large extra expense to overcome and which militate against the use of air motors.

When air is compressed by mechanical means the temperature is raised, and if none of the heat is allowed to escape it is said to be "adiabatically" compressed, and in working by expansion back to atmospheric pressure, as when expanded behind a piston, there is an extreme fall in the temperature, causing ice to form about the cylinder and valves,

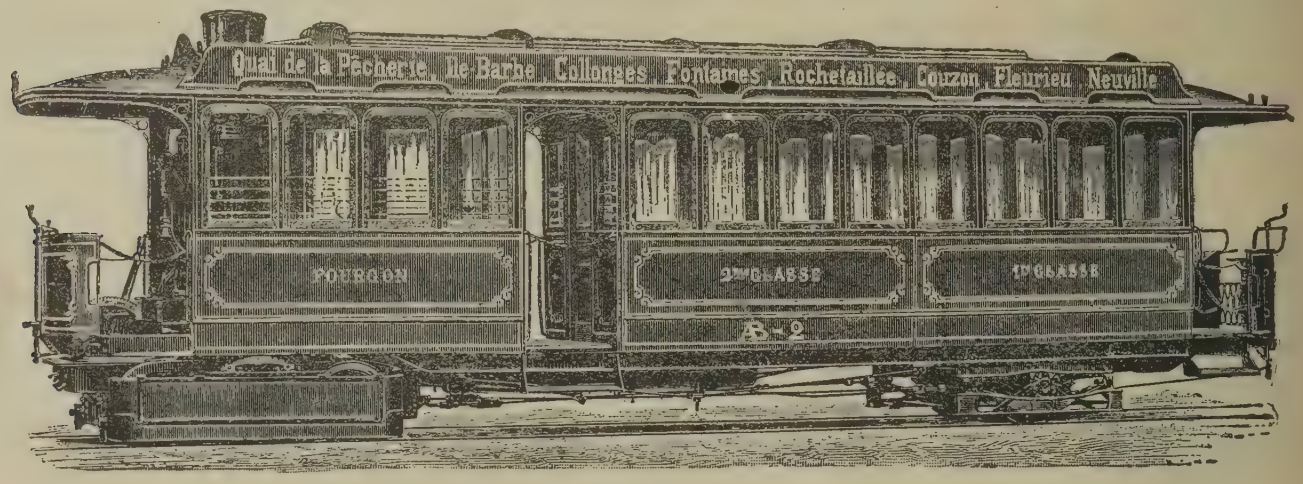


FIG. 321.—ROWAN'S STEAM TRAM CAR.

and so hardening the lubricant as to render the engine inoperative. For this reason, the working of air expansively is confined to narrow limits, and only by adopting some means for checking the fall in temperature, can it be used to advantage.

The most efficient means adopted for this purpose are either to heat the air before expansion by passing it through a furnace, or by saturating it with vapor, in which case the vapor is condensed during expansion and its liberated heat is absorbed by the air, preventing freezing.

To keep the rise of temperature during compression within reasonable limits, the cylinders of the compressing pump must be jacketed with running water.

Foreign engineers have succeeded in adapting air motors to tramway purposes, better than those of our own country, while in the use of compressed

air, for working drills in mines and tunnels, our home engineers have had remarkable success.

The most successful air motor of which we have

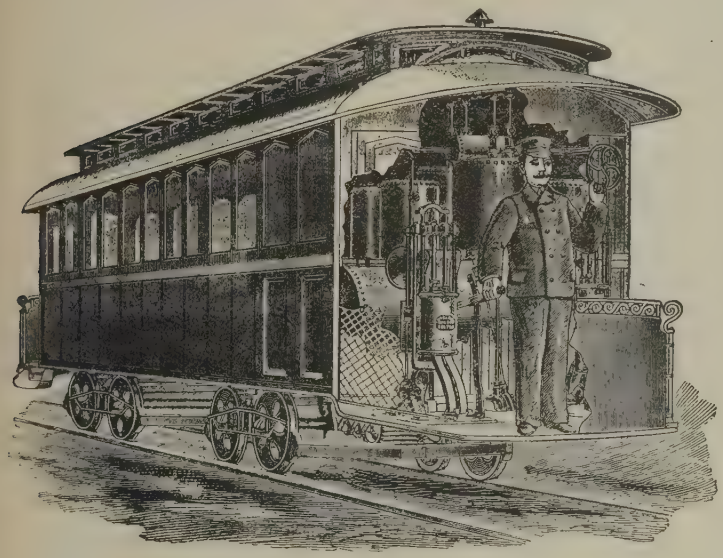


FIG. 322.—STORED STEAM MOTOR.

any knowledge is the Mekarski, which is in use in the city of Nantes, France, and on several other lines in the same country, and is being experimented with in this country (Fig. 323A).

The motor may be described as follows: The appearance is like an ordinary car, with reservoirs made of half inch steel plates, nine in number, placed under the floor of the car parallel with the axles, and which are tested to sustain a pressure of 900 lbs. per square inch. These reservoirs are divided into two groups; the first group is composed of six reservoirs having a total volume of 536¼ gals.; the second group or remaining three reservoirs, called the reserve, contain 281½ gals.; total total capacity 817¾ gals. This volume of air under a pressure of 675 lbs. per square inch, weighs 380 lbs. The reserve battery is made independent

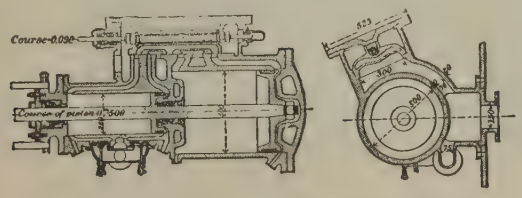


FIG. 324.—CYLINDERS OF MEKARSKI MOTOR.

and always kept at a high pressure so that an extra powerful effort may be given to the engine in case of need on steep grades or at the end of the trip. The different reservoirs are connected with a system of strong piping, and the pipes from both groups are led to the lower part of a cylindrical reservoir placed vertically on the front platform of the car (Fig. 323). This reservoir is made of steel, contains fifty-three gallons and is charged with water under pressure and at a temperature, at the outset, of 311 degs. F. The air passes through the water in the form of bubbles, becomes heated and at the same time saturated with vapor, and collects in the top part of the cylinder which serves the purpose of a steam dome in a boiler. On the top of the cylinder is a pressure regulator which the engineer operates to reduce the pressure of the air going to the cylinders to sixty or seventy-five pounds per square inch. There are also two manometers on the dome to indicate the pressures in the battery and in the reserve.

From the regulator the air passes to the cylinders which are arranged in sets of two, each pair

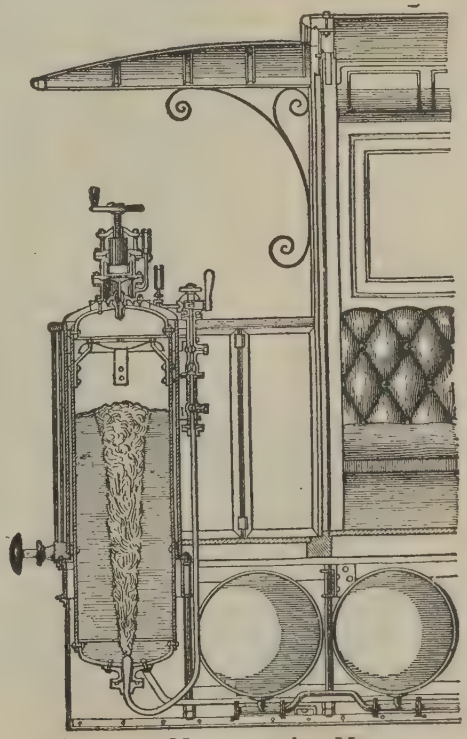


FIG. 323.—MEKARSKI AIR MOTOR.

forming a tandem double expansion engine (Fig. 324). The two cylinders of a set are of different diameters and are cast in one piece. The air is ad-

mitted to both cylinders in succession by the means of the same compound slide valve. The total proportion of expansion is about six volumes. The cylinders have outside connections and the two pairs of wheels are coupled. The machinery is protected by sheet iron boxing. The car, it is claimed, will make a run on easy track of twelve and a half miles without recharging; on grades nine miles. Stations are provided for compressing the air, and in the operation of charging the

FIG. 323A.

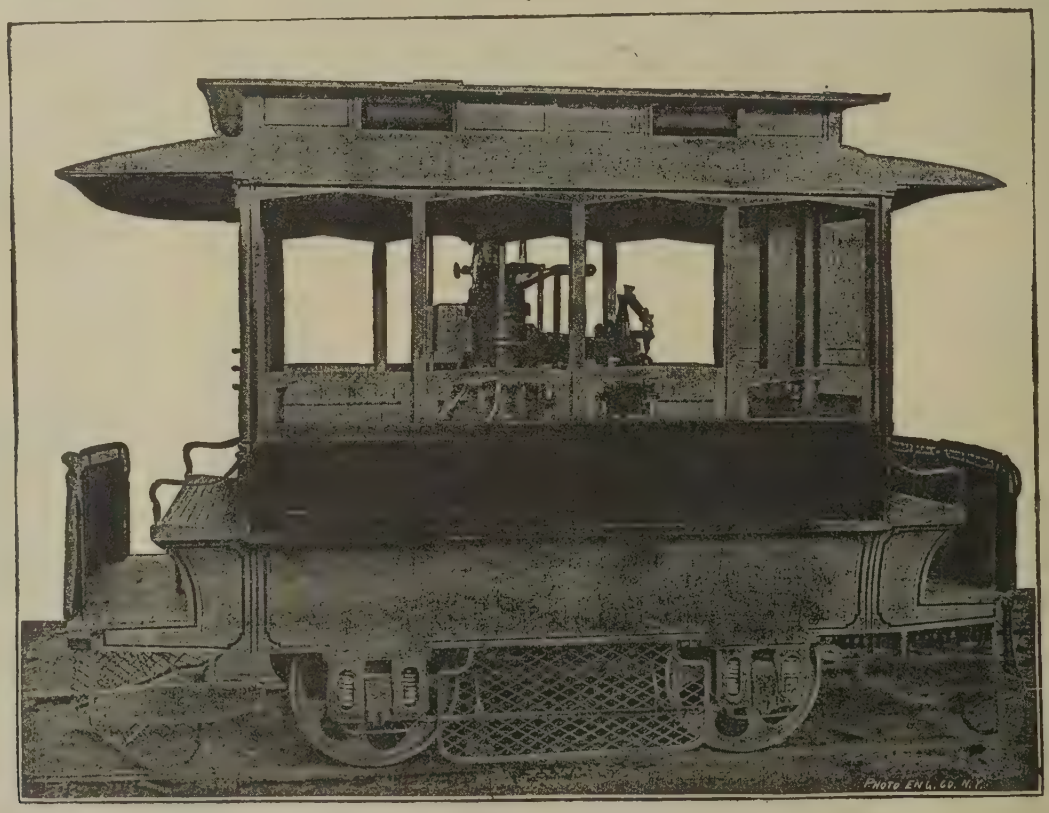


FIG. 325.—CONNELLY GAS MOTOR.

cars are brought opposite the station reservoirs, and the air and the steam which heats the water are led by pipes to the corresponding tanks on the car. The duration of charging is about fifteen minutes.

It is claimed for this system that about forty per cent. of the initial power is utilized for moving the car. The car makes a daily run of sixty miles at a total cost, including wages and repairs, of $6.50 per day, or ten to eleven cents per mile

Referring to the phenomena of temperature in relation to compressed air, if air be subject to compression, so that the pressure be doubled, trebled, etc., or so that, taking the initial pressure at 62 degs., as 1, the relative pressures as 1, 2, 3, 4, 5, 10, the final temperatures are 128 degs., 158 degs., 258 degs., 321 degs., 373 degs., 559 degs. It will be seen that air cannot be employed at these high temperatures.

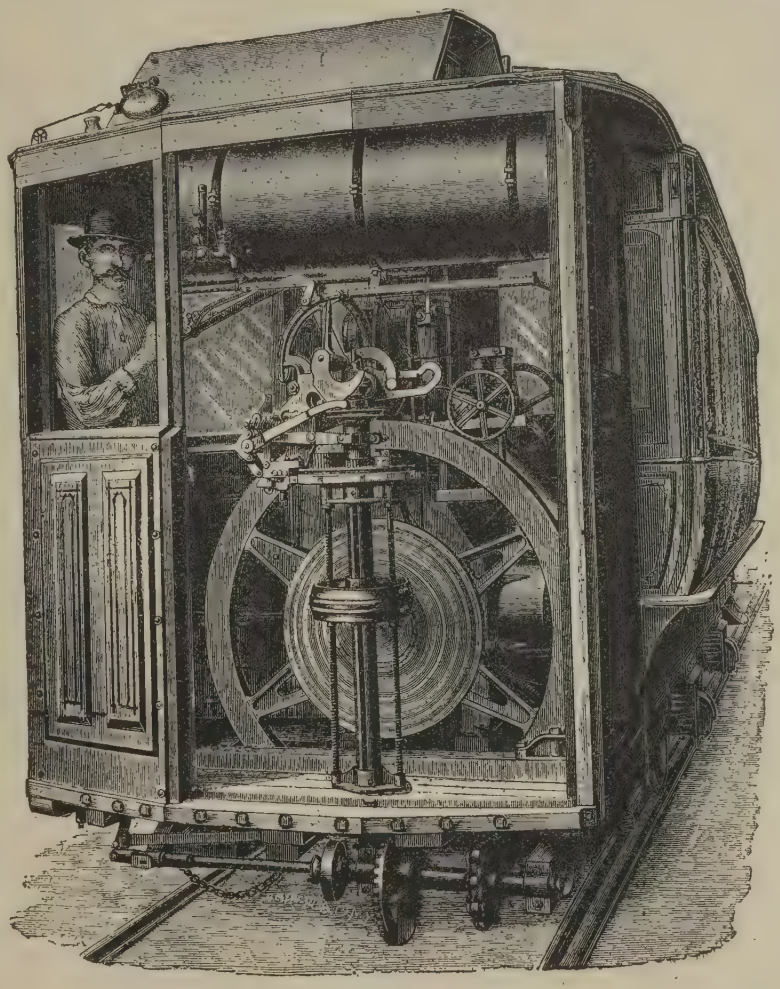


FIG. 326.—CONNELLY GAS MOTOR AND CAR COMBINED.

Again, when the initial temperature is 62 degs. for ratios of "adiabatic" expansion, 2, 3, 4, 5, 10, the final temperatures are —33 degs. —81 degs. —111 degs —133 degs —193 degs. So that it is clearly impracticable to work a compressed air engine in such low temperatures.

GAS MOTORS

have been brought out from time to time, and may be divided into three general types. Those that are operated by the expansion of gases generated by chemical action, those operated by steam generated by the heat of chemical action, and others burning naphtha gas manufactured on the car.

Experimental cars of the first type have a reservoir of hot water placed on the roof of the car or in other positions, having an interior reservoir containing liquid ammoniacal gas, produced by heating sal ammoniac in the presence of hydrate of lime. The gas, being disengaged under the influence of the heat of the surrounding water, is passed to the cylinders which may be placed vertically at the end of the car, and connected to a crank shaft below, from which a link chain connects with a pulley on the axle of the car.

The exhaust is led into the reservoir of water, where it is condensed, imparting its heat to the water. This process of expansion and condensation, may be continued until the pressure of the gas in the interior reservoir becomes insufficient for keeping the piston in motion.

When the water becomes saturated with gas it may be replaced, and the absorbed gas can be extracted from the first charge for further use. No satisfactory results are reported.

The second class, or soda motors, have not yet become a commercial success.

Figs. 325 and 326 illustrate a promising motor of the third class, from which good results have been obtained. The fuel or expansion agent is naphtha

gas, manufactured on the car. A cylindrical tank enclosing a second tank is located in any convenient position, shown, in the figure, under the hood. The inner tank contains naphtha and an absorbent material. The space between the shells is filled with water, which is connected by pipes with the water jacket of the gas engine, of which there are two cylinders, and is heated by the radiation from the cylinders. Air, being drawn through the inner tank, is thoroughly carbonated and passes to the cylinders, where it is compressed and exploded by an electric spark generated by a small dynamo attached to the machine, as shown in the figure.

The pistons are attached to the crank shaft at different angles. A flywheel is provided (Fig. 326), having on its overhanging face a metal disc. A friction pulley twelve inches in diameter, supported on a vertical shaft, engages with the face of the disc, and may be moved up or down on its shaft by means of two screw rods shown in the figure. The engine being started, runs continually, and the speed and direction of the car are controlled by an ingenious arrangement of levers which move the friction pulley to or from or below the centre of the disc. In starting, rounding short curves or ascending steep grades, the contact may be maintained near the centre, thus securing sufficient power for all purposes with an eight H. P. engine only. The vertical shaft transmits power to an intermediate shaft by means of beveled gear, and the intermediate is connected by a sprocket chain with the axle.

The engine may be mounted as an independent motor (Fig. 325), or a combined car be used. The engine emits little or no smoke or odor, and is operated with a very small outlay for fuel.

CHAPTER V.

INCLINED PLANES.

Inclined planes or, more properly, incline railroads, have a very early history, and were originally designed for transporting passengers, freight and coal for short distances upon grades too steep to be surmounted by the ordinary methods of traction, and are practical upon grades having a rise of from fifteen to seventy-five feet in 100. The most important inclines and the most numerous, in this country, are located at Pittsburgh, Pa., and Cincinnati, O., while isolated plants are to be found in different localities.

The T type of rail is usually employed, and the rails are laid on ties resting directly on the surface of the ground or, where the grade is not suitable, upon viaducts constructed of wood, masonry or iron. Inclines are usually built in straight lines with double track having a gauge of from five to ten feet, but are sometimes operated around curves having a long radius on which horizontal pulleys about three feet in diameter are employed for deflecting the rope. These roads are also constructed with three rails having a turnout midway between terminals, and a very few foreign lines have two rails with turnouts, while in one instance, that of the Mount Vesuvius incline, a single rail is employed, and the car runs on a centre wheel with two angle wheels (Fig. 327). Viaducts for inclines are most commonly constructed of steel, the plate type of girder being generally employed for short spans, while the spans range from thirty to 120 ft.

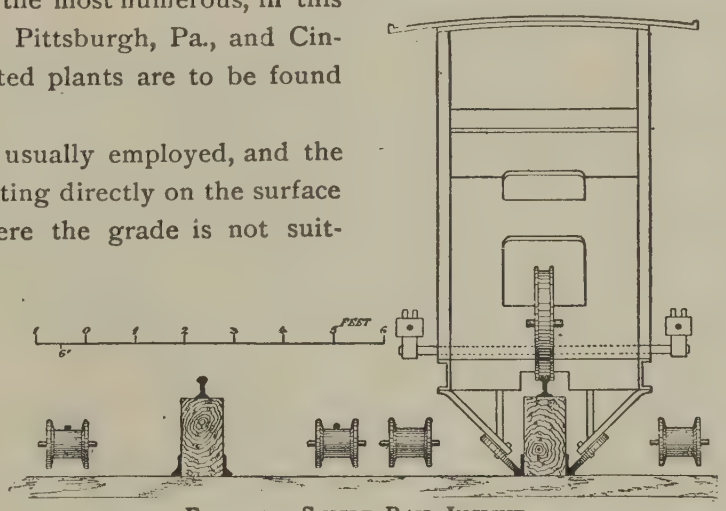


FIG. 327.—SINGLE RAIL INCLINE.

The general features of an ordinary incline are illustrated in Fig. 328, in which it will be seen that two cars of peculiar shape are operated and so arranged that one ascends while the other descends, the speed being, usually, about 600 ft. per minute. The cars are moved, ordinarily, by being permanently attached to the terminals of strong wire ropes from one to two inches in diameter, of which there are generally two, one being employed as the hauling rope, and moved by being coiled upon large drums located at the head of the incline, to which the power is applied; the other, known as the safety rope, which passes over a sheave at the top, and serves to balance the cars and to stop them, the speed being regulated by a band brake on the safety sheave. On very heavy lines two hauling ropes are employed.

The power equipment of an incline is usually located beneath the floor of the station at the upper landing, on a direct line with the track, and the ropes are led in from the tracks to the drums over large pulleys (Figs. 329 and 330). In case the real estate at the head of the incline is too expensive, the hoisting machinery may be located on the side of the plane, in which case guide pulleys are provided to lead the ropes into position. In some instances, in place of wire ropes, the cars are hauled by means of flat, thin, steel strips, from three to six inches wide, welded or riveted into a continuous belt, which is moved by being coiled upon the winding drums like a spool of ribbon. The life of

wire ropes on inclined planes is, usually, from two to five years, depending upon the amount of traffic.

The winding drums are from eight to eighteen feet in diameter, with a width depending upon the length of rope to be coiled. They are, usually, of cast iron having a wood lagged surface, but are sometimes provided with a metal surface having spiral grooves in which the rope rests. In some cases a sliding guide is provided to lead the different wraps into position, so as to prevent the incoming rope from chafing against the neighboring wrap. The hauling ropes may be attached to the opposite sides and ends of a single wide drum, so that as one rope unwinds the other will wind on in the same grooves; or, separate drums may be provided for each rope, (Fig. 330). In some instances, where the line is an unusually long one, the rope is driven by a pair of winding drums in about the same manner in which the rope on a cable street car line is moved (Fig. 331).

Double, reversible engines are best suited for driving the winding drums of an incline; or, two engines may be employed, which should be attached to the same crank shaft at different angles, from which the power is transmitted to the drums by means of pinion and gear. The ropes are usually supported in the bed of the track by carrying pulleys made either of wood or iron. Pulleys made of the latter material are the most durable and do not wear the rope to any great extent.

The position of the operating engineer for an incline road is, usually, in a cab located at the head of the incline, with sufficient elevation to overlook the entire line (Figs. 329 and 330), where, by means of levers attached to the throttle valves and brake appliances he controls the movements of the cars. In a few instances, however, where it is necessary to operate the incline with great economy, one man only is employed, who acts both as engineer and conductor, in which case the operator is provided with a cab on one of the cars and controls the engines from the car by means of a still, endless

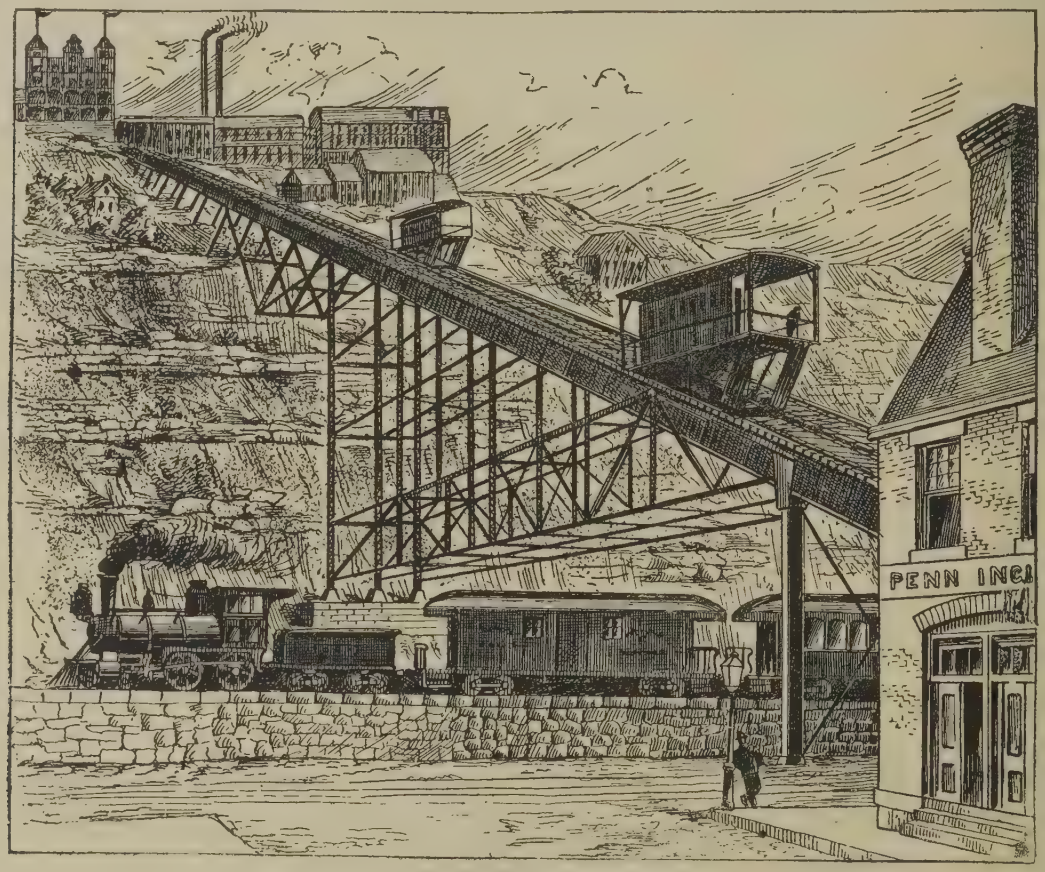


FIG. 328.—PENN INCLINE.

manilla rope laid along the bed of the track which wraps a small sheave that is connected with the throttle valve in the engine room at the head of the incline, and also passes around a loose sheave at the foot. A loop from one arm of the manilla rope is brought up into the car between two guide sheaves located near the surface and over a sheave on the side of the cab near the roof. As the car moves up and down the rope passes over the loose sheave, the friction not being sufficient to impart any lateral motion to the rope. The operator, however, by grasping either arm of the rope can cause it to move sufficiently in either direction to operate the throttle valve. In case this method of operation is adopted, one of the cars is run simply as an idler to balance the weight, and passengers are allowed only on one car.

FIG. 329.—TRANSPORTING ELECTRIC CAR—MT. ADAMS & EDEN PARK INCLINE, CINCINNATI.

The cost of constructing inclines depends largely upon the character of the surface over which it is to pass. In case the hill is a regular slope, so that the track can be built directly upon the surface (Fig. 332), the cost of construction will be much less than where the surface is irregular and it becomes necessary to provide viaducts.

In order to give a general idea of the cost, the following particulars are given descriptive of lines in actual operation.

No. 1. Duquesne Incline, Pittsburgh. The total length of this is 780 ft., the grade fifty-eight and a half per cent., and the total rise 400 ft. The lower portion of the bluff being very abrupt, and it being found necessary to cross the lines of a steam road at the foot of the bluff, the lower 300 ft. was built of five foot, riveted girders in spans of sixty feet, the remaining portion being constructed of twenty-four inch, riveted girders of thirty feet span. The gauge is five feet, and the track is laid with forty-five pound steel T rails. The hoisting and safety ropes are each one and one-quarter inches in diameter. The power equipment consists of a pair

of 14 × 25 ins. engines, and the ropes are driven by a single cast iron drum having a grooved surface, with the ropes so attached that they wind on and off alternately. The cars, which are designed for passengers only, have a capacity of carrying forty persons at a single trip. The entire cost of this plant was about $55,000.

No. 2. St. Clair Incline, Pittsburgh. The tracks

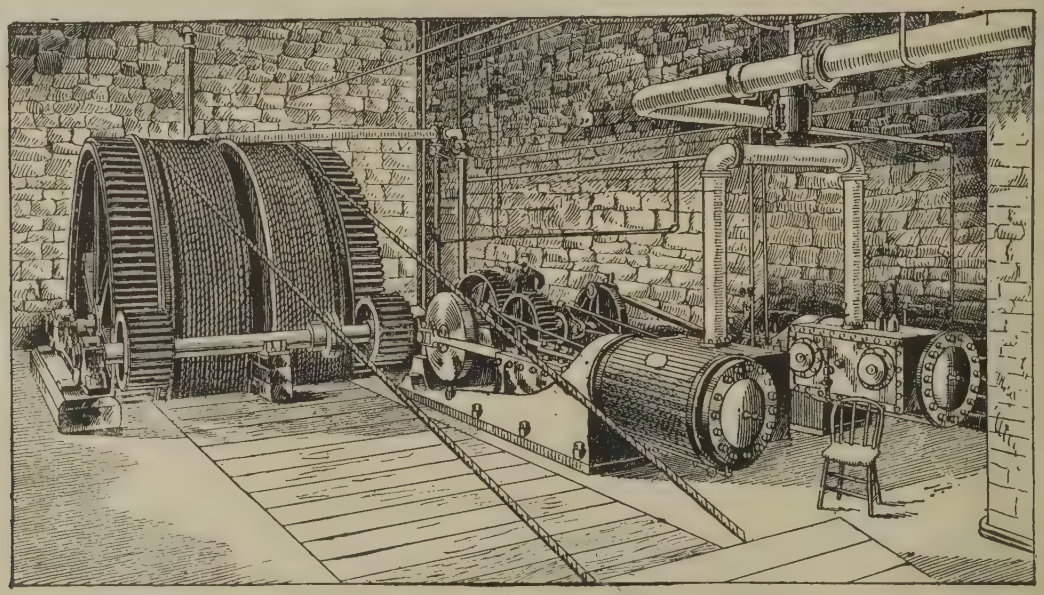


FIG. 330.—POWER STATION—PENN INCLINE.

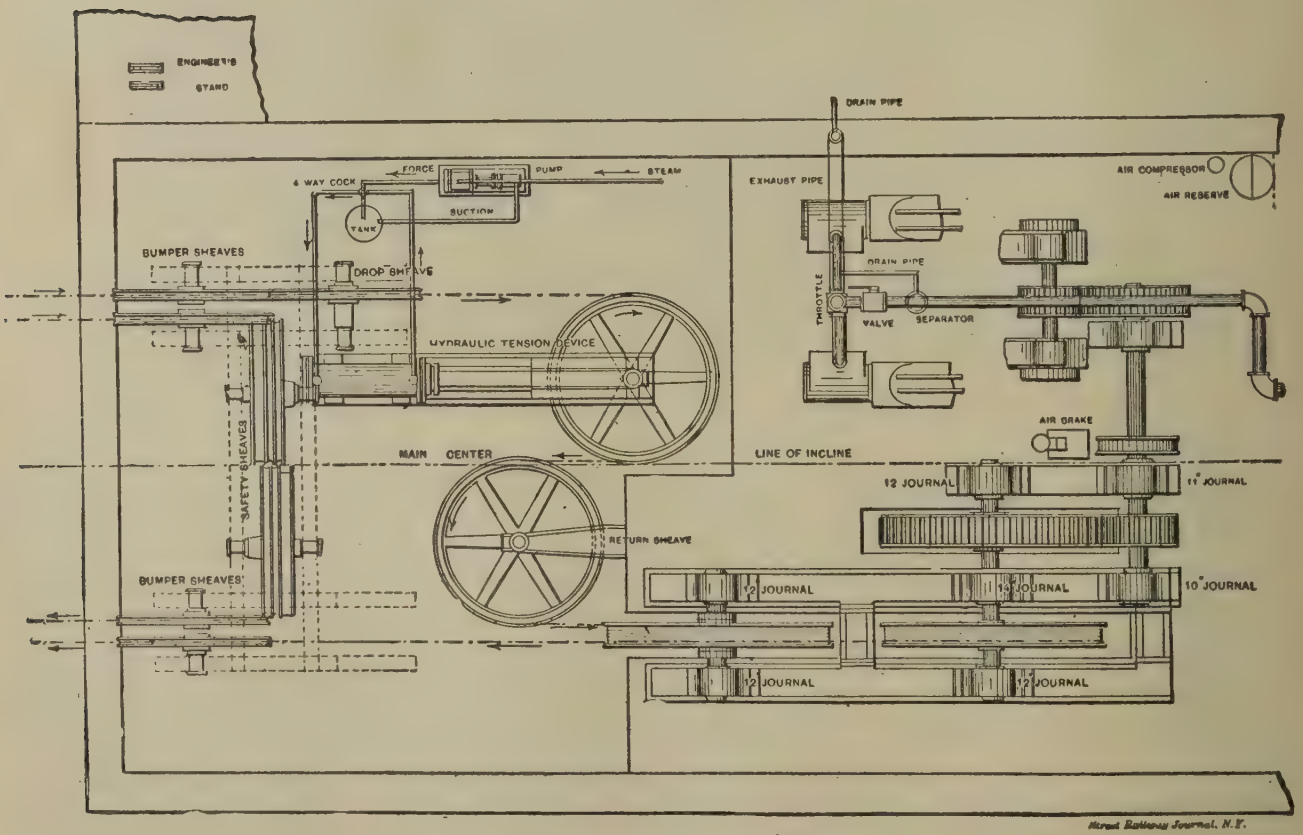


FIG. 331.—ROPE DRIVE—DULUTH INCLINE.

are laid on the surface to the summit of the bluff, the entire distance being 2,060 ft., with a rise of 361 ft. The plane is not uniform, but the grades do not vary so much but that the weight of the ropes keeps them in position. This incline is used for transporting both freight and passengers, and the ropes are one and three-quarters inches in diameter. The gauge is seven feet, and forty-five pound steel T rails, spiked to white oak ties, are employed. The lifting capacity of the incline is twenty-five tons per car. The power equipment consists of a pair of 14 × 36 ins. engines which operate the drums by means of an intermediate counter shaft and gear. The single hoisting drum is sixteen feet in diameter, of cast iron, with grooves. This incline was built for about $60,000.

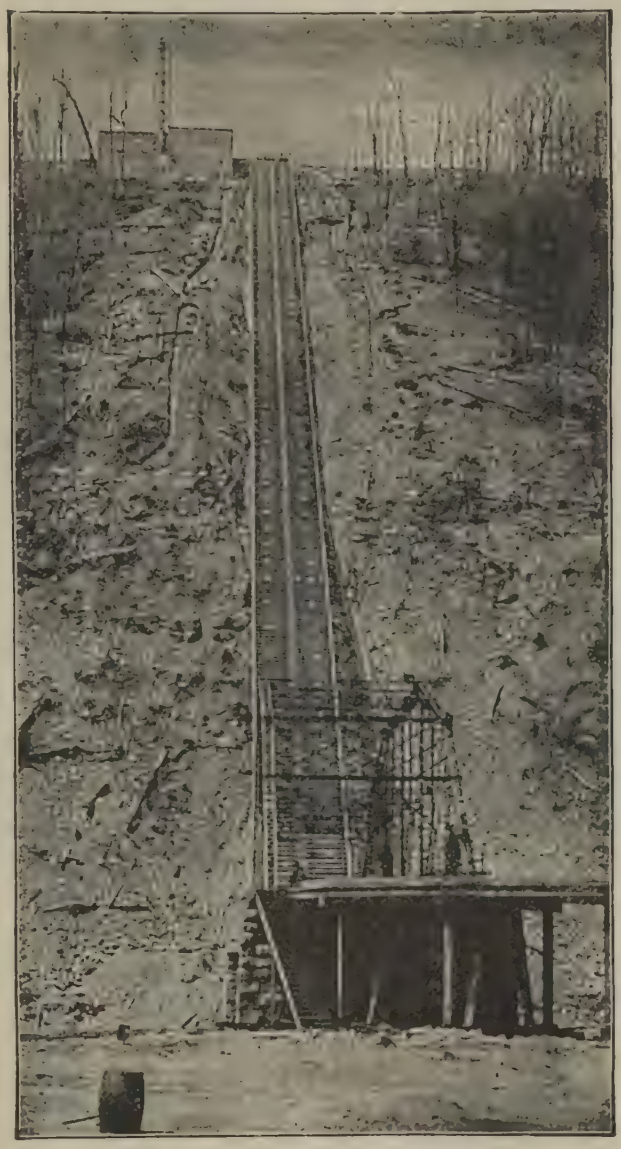


FIG. 332.—INCLINED PLANE—JOHNSTOWN, PA.

No. 3. Penn Incline, illustrated in Fig. 328, is one of the most heavily built and expensive lines ever constructed, and was designed with sufficient capacity to haul twenty tons of coal at a single load. The total length is 840 ft. and the total rise 330 ft. the average angle being twenty-three degrees. The road bed is carried the entire length on heavy riveted plate girders five feet in depth. The lower section consists of a single span of 232 ft., the second section of another span of 120 ft., while the remaining portion of the structure is in sixty foot spans. The rails are sixty pound T, spiked to 10 × 12 ins. white oak ties, and the gauge is ten feet. The power equipment consists of a pair of 24 × 36 ins. engines, and the drums are of cast iron eighteen feet in diameter, with grooves for the ropes. The car platforms are 16 × 38 ft. and the truck is made of channel iron. Two hoisting ropes are employed, each two and a quarter inches in diameter. The carrying pulleys are ten inches in diameter, of cast iron, with groove. Over 750 tons of iron were used in the truss construction, and the entire cost, including the power equipment, was $320,000.

No. 4. Knoxville Incline, Pittsburgh, illustrated in Fig. 333, has a total length of 2,640 ft. and a rise of 375 ft. The lower section, for a distance of 980 ft., is built of iron work in spans of from twenty to seventy feet, the plate girders being from twenty-four to thirty-six inches deep. The remaining portion is built on the surface. At about 1,000 ft. from the bottom the track makes an eighteen degree curve for the distance of 350 ft. The ropes are deflected around the curve by thirty inch horizontal pulleys. The gauge is nine feet, and sixty pound steel T rails are employed. The power equipment consists of a pair of 18 × 36 ins. engines which are connected to the shaft of the drum by a pinion and spur gearing. Two drums are employed, one twelve and one half feet in diameter, and the other

a trifle larger in order to compensate for the additional length of rope required for the outward track of the curve. The hoisting and safety ropes are one and three-quarters inches in diameter. The cars are 16×47 ft. and are designed to carry fifty tons. The cost of this incline with equipment was about $190,000

Safety devices are the most important appliances connected with the operation of the inclines. To guard against the possibility of an accident, the following devices or their equivalent are recommended. Duplicate throttle valves should be provided, or, in place of one, a butterfly valve in the steam pipe may be substituted. This should be operated by a separate lever or cord extending to the cab in convenient position to be readily reached by the engineer. The butterfly valve should also be arranged to close with a spring or weight, and it should be connected with the brake device so as to operate in unison with it. This precaution is necessary from the fact that accidents on inclines have occurred from the inability of the engineer to stop the engines when the cars had reached the terminals, owing, in one case, to a small bit of metal becoming lodged in the valve seat. In this case the ropes were torn from the car, which allowed it to descend with fatal results. On some lines a lever mechanism is provided, by means of which the car as it approaches the upper landing closes the throttle and sets the brakes. This device is provided in case the operator should suddenly become incapacitated from sickness or any other cause. Another means of providing against the possibility of the operator failing to perform his duty consists of an attachment to the throttle lever latch which closes the steam valve in case the operator should release his hold of the latch. Band brakes operated by a foot lever should be applied to the safety sheaves sufficiently powerful to stall the engine. Pneumatic brakes should also be provided to supplement the lever brake. The hauling and safety ropes are usually attached to separate cross beams on the truck so that in case one beam should be torn out, the car would be held with the other. In the bed of the track, or at the sides of the track near the landing, heavy automatic latches or hooks should be arranged which will close over a cross beam of the truck as soon as a car reaches the top landing, so that the car will be safely held should all the ropes be removed. Electric signals and telephones are important appliances which will enable the operator in the cab

FIG. 333.—KNOXVILLE INCLINE—PITTSBURGH, PA.

to communicate with the guard at the foot of the incline and by means of which warning signals for starting may be given. It is the usual practice to give three separate signals before the cars are set in motion. Good practice requires that a careful inspection of the entire line be made each morning by the chief engineer before the line is started up

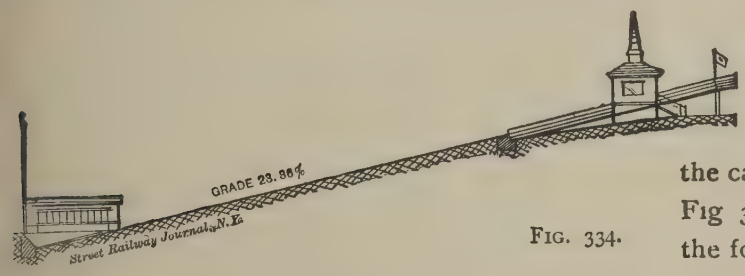
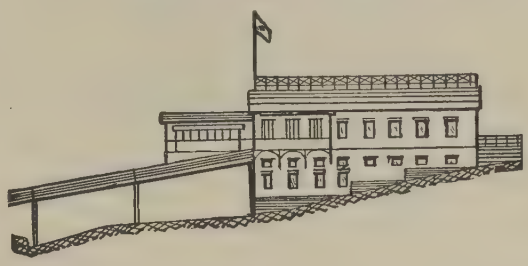


FIG. 334.

for the day. And the first trip each morning should be a trial trip with empty cars to make sure that everything is in working order. It is a rule on some lines to require that the chief engineer operate the cars for an hour or two each morning to make sure that all the appliances are working in a proper manner. To avoid heavy bumping at the lower landing the cars should be provided with spring or pneumatic bumpers, preferably the latter, which should have a stroke of about sixteen inches. The cars should also be provided with powerful headlights, and there should be lights at the head and at the foot of the incline.

Fig. 334 illustrates a section and the terminus of a long incline which is constructed partly upon the surface and partly upon a viaduct. In this case there is also provided a way station at which the cars stop.

Fig. 335 is an elevation of the power station and



the car at the upper landing of the same line, and Fig 336 is a longitudinal section of the car pit at the foot of the incline.

The cars for inclines, it will be noted from the illustrations, are usually supported on eight wheel, triangular shaped trucks, which are built of wood or of channel iron, the triangular form of the car being necessary to maintain the platform as near a level position as possible, so that it may be readily

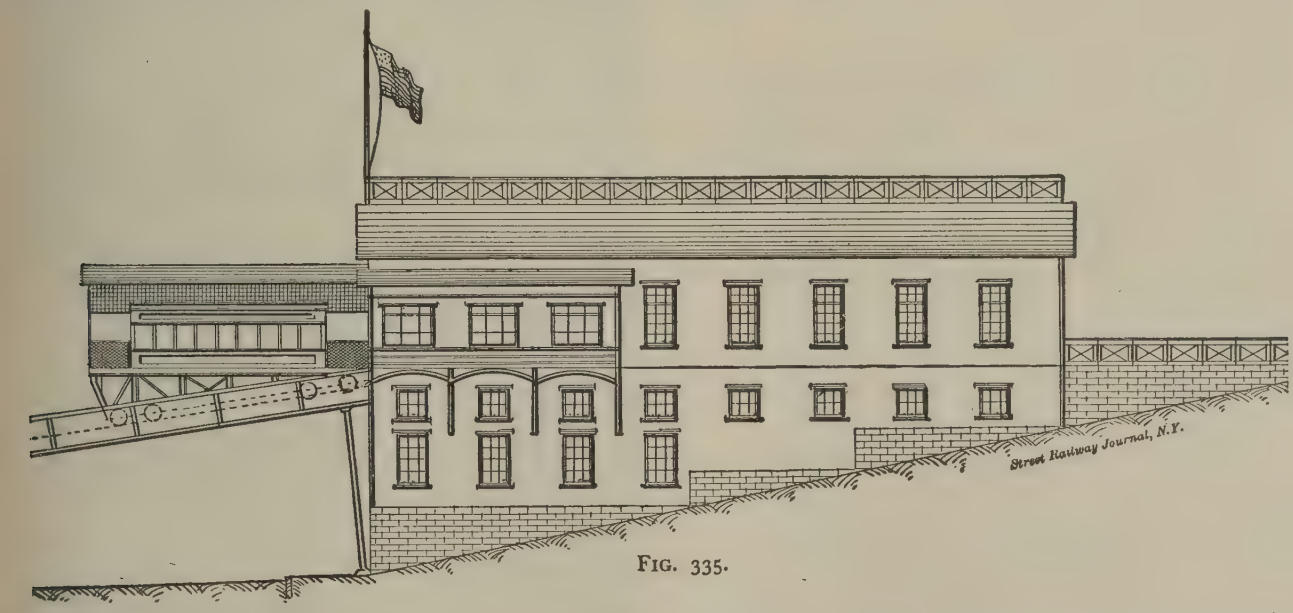


FIG. 335.

boarded at the landings. In some cases, where freight and passengers are both transported, the passenger apartment is arranged in the truck beneath the main platform, and in others to one side of the platform, as in Fig. 328.

Cars for inclines are usually from twenty to thirty feet in length, and from twelve to sixteen feet wide, and weigh from fifteen to twenty tons. They may be roofed or open, and are usually pro

vided with strong iron railings with gates at the ends to prevent the possibility of wagons being crowded off the platform should the teams become

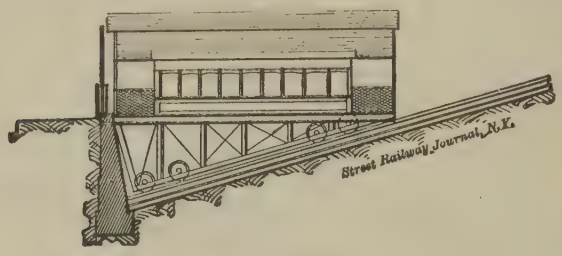


FIG. 336.

restless or unmanageable. On lines where electric street cars are transported, it is common to provide an adjustable bumper, which can be swung into position when the car is loading, to guard against the danger of its running off the platform in case the brakes should not act properly (Fig. 337). This bumper may be arranged to drop down beneath the platform when the car is to leave the incline. The platform of the incline car should also be provided with chains and blocks for locking the wheels of loaded vehicles in position.

Figs. 330 and 331 show the arrangement of the engine and machinery of a plant which is designed for operating a very long line, in which the rope is driven by making a number of wraps on a pair of winding drums in about the same manner as for a cable line. The boiler room for this plant is located to the right, but is not shown in the engraving. In this particular plant the safety rope is led over four sheaves, two of which are provided with band brakes, as shown in the illustration, and by means of which the speed of the hauling rope can be quickly checked. A hydraulic tension device is connected with this plant, as shown, which is employed for more readily adjusting the hauling rope. By means of a small force pump the tension sheaves are forced forward and the slack of the hauling rope is taken up. This is an important matter, from the fact that the cars must always land within an inch of the bumpers at either end of the plane, and as the length of the rope varies with the temperature, and is gradually elongated from wear, the adjusting mechanism is necessary. The same end may be accomplished by means of weighted sheaves, but these are not so prompt in their action as the hydraulic device. The slack in the safety rope may be taken up by means of an adjustable attachment to the cars.

In some localities, mostly in foreign countries, however, where there is an abundant supply of water, inclines are operated, not by steam power but by the weight of stored water. The cars being provided with suitable tanks, a load of water is taken on to the car at the head of the incline, which causes it to descend with sufficient force to haul the other car up the grade. On reaching the bottom the water is discharged from the first tank while the one at the top is again filled. By alternately

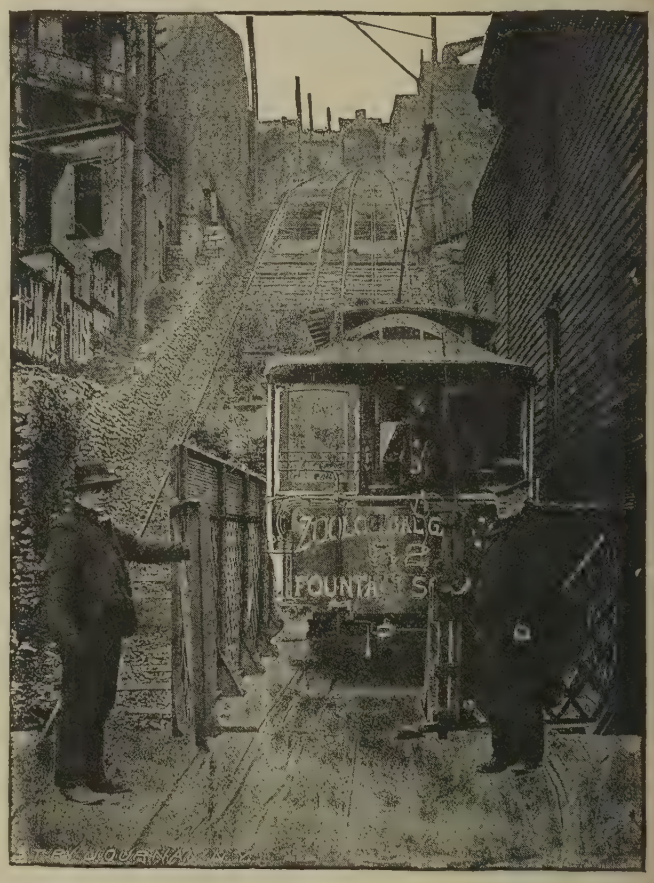


FIG. 337.—ELECTRIC CAR ENTERING INCLINE PLATFORM—CINCINNATI INCLINED PLANE.

filling and discharging the tanks the cars are kept in operation. In case the building of an incline is contemplated, parties interested can learn full particulars by addressing the local engineers in the localities where such lines are in operation.

CHAPTER VI.

RACK RAIL INCLINES.

Rack rail inclines are admirably adapted for transit over steep grades where the line is too long to be operated by the ordinary incline system. It may be interesting to note that almost the first locomotives built were designed to operate on the rack system, and that as early as 1812 a line for transporting coal was opened in England, and was operated by rack and pinion for twenty years, and in 1847 a bold attempt was made in this country to adapt the rack and pinion to the requirements of a regular railway line, and from that time to this the problem of how to climb long, steep inclines on railways has taxed the inventive genius of many clever engineers.

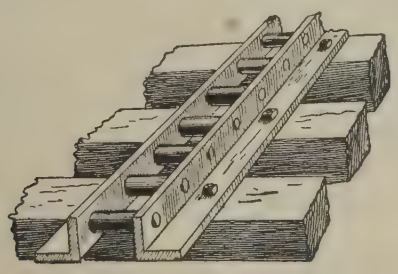


FIG. 338.—RACK RAIL.

Among the early devices for climbing steep grades was a plan for equipping the regular locomotive with a pair of horizontal friction rollers arranged to press against a smooth centre rail and operated by a special set of cylinders; but in the system which first gained prominence in this country the rack took the form of a narrow ladder, having angle iron sides and bar iron rounds one and one half inches in diameter, and placed four inches apart, which answer for teeth or cogs (Fig. 338). One of the most important lines constructed after this plan is that on the slope of Mount Washington in New Hampshire (Figs. 339 and 340). This line is about three miles in length, with grades ranging from ten to thirty-seven and a half per cent., the average being twenty-five per cent. The rack and track rails are spiked to wooden ties which are securely anchored by straps and bolts to the solid rock formation. The low places are spanned by substantial trestle work.

Although the ladder rack rail system has come into quite extended use it has serious inherent defects which incapacitate it for high speeds. The prime requisite for a smooth and quiet motion in all gearing is uniformity of pitch, especially at high speeds, and it is almost impossible to manufacture a long ladder rack without introducing elements of error. Again, the diameter of the pinion, to secure proper contact with the teeth, is so large

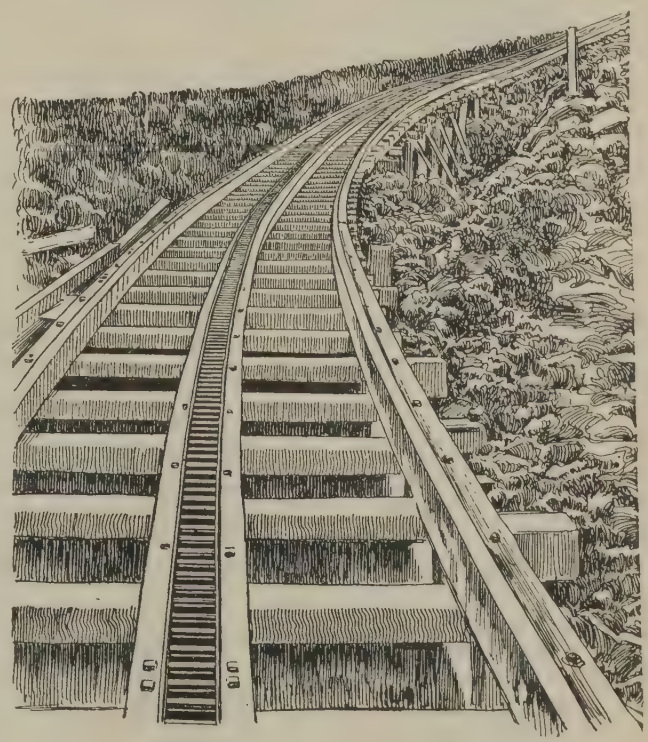


FIG. 339.—MOUNT WASHINGTON RACK RAILWAY.

that the power from the steam cylinder has to be transmitted to it by multiple gearing.

On account of the defects enumerated above and

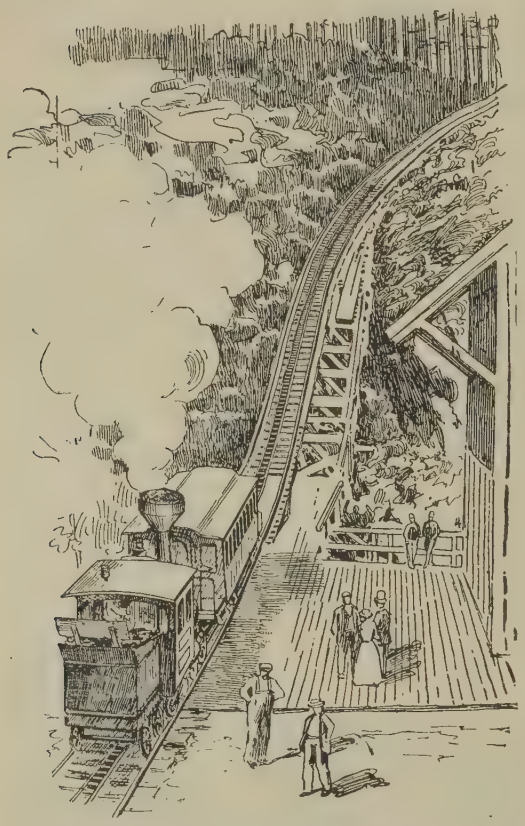


FIG. 340.—ENGINE AND CAR—MOUNT WASHINGTON RAILWAY.

others, the tendency of modern practice has been to abandon the ladder type and adopt a rack which is essentially built up of two or more individual racks placed side by side. This particular construction is known as the Abt system and is employed to a considerable extent on lines in Switzerland and Germany and on a few lines in this country. The elementary rack (Fig. 341) is a flat bar of given length, provided with teeth. These bars are connected together by steel chairs, which are placed at regular intervals, and serve to keep the bars laterally distant from each other, and also to secure the rack to the ties of the roadbed. At intervals, depending upon the grades, anchorages are made by straps of iron fastened to the ties and carried up grade and fastened to eye bolts set in solid rock, or in blocks of masonry. The various bars of which the rack rail is composed are laid with broken joints and the teeth are staggered, or in the form of steps which enable the simultaneous contact of several teeth of the pinion with different bars of the rack rail, thus giving a contact and smoothness of motion that it is difficult to obtain with the ladder type, and offers increased security against the fracture of a tooth.

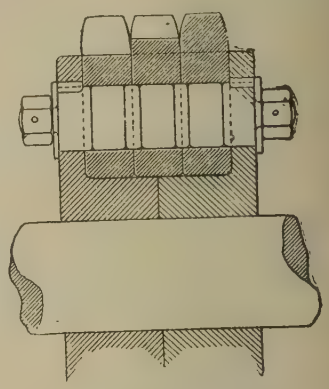


FIG. 342.—PINION—RACK RAIL LOCOMOTIVE.

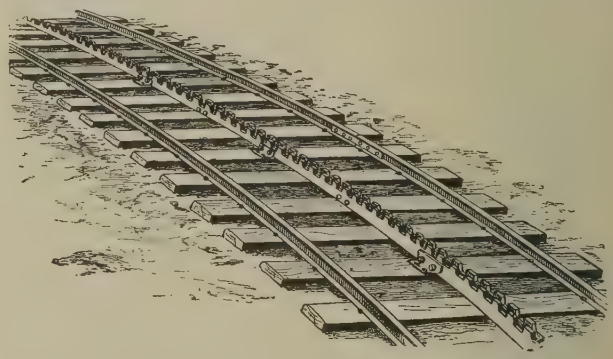


FIG. 344.—RACK RAIL—CURVE CONSTRUCTION.

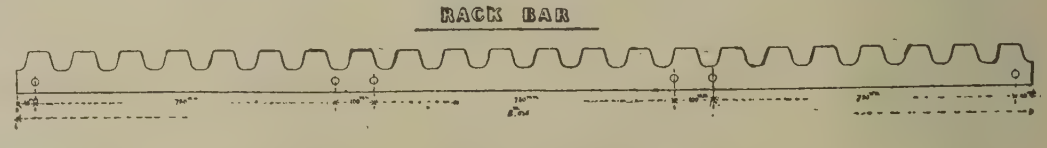


FIG. 341.—RACK BAR.

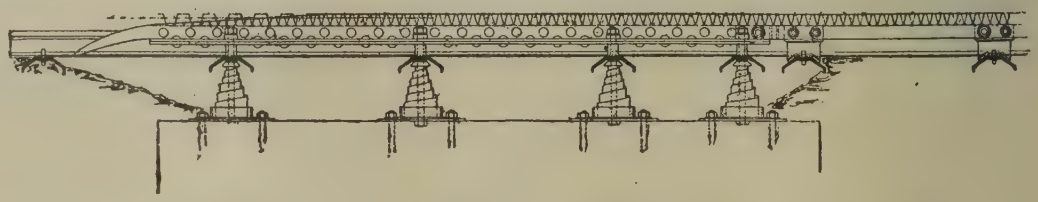


FIG. 346.—ENTERING RACK RAIL.

The pinion (Fig. 342) is constructed of as many separate disks as there are separate bars in the rack rail, and the disks are shifted against each

other according to the stepping of the teeth in the bars, and are held in elastic connection with the shaft by means of inserted springs. By this arrangement the different disks have a small, limited, relative motion to each other, so that an absolutely perfect automatic contact of the teeth of the pinion with those of the rack is established, and, at a speed as high as sixteen miles an hour, a smooth motion is obtained, free from blows or noise.

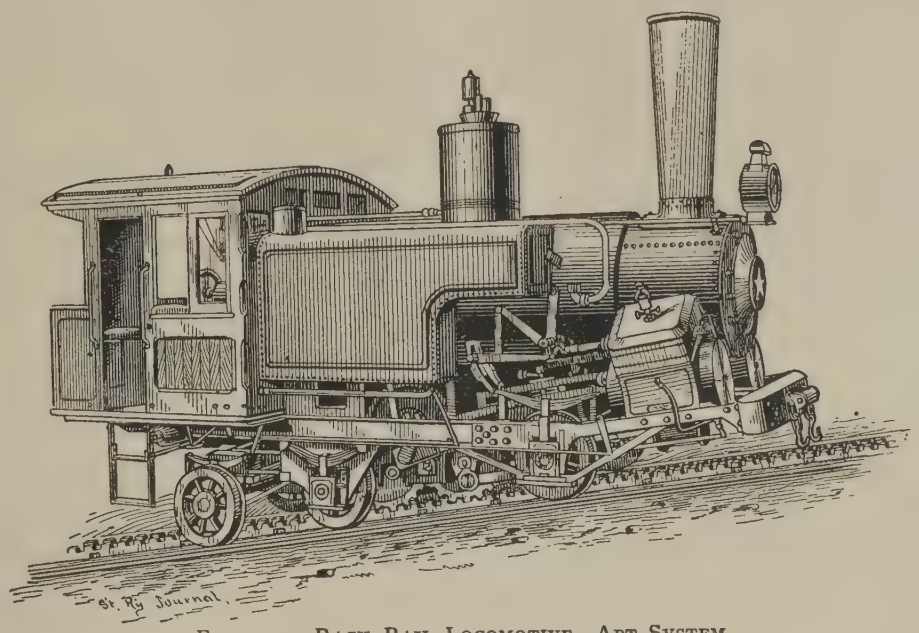


FIG. 343.—RACK RAIL LOCOMOTIVE—ABT SYSTEM.

343), coupled together. These pinions are about two feet in diameter, and are driven from a drum by means of a walking beam without intermediate gearing. With this system, curves of ordinary radius are operated with ease (Fig. 344).

As a means of safety, and for other reasons, the locomotive on this class of roads is placed at the rear of the train and pushes it ahead, as shown in Fig. 345, the same being an illustration of a train ascending Pike's Peak, Colo., the line being nine

FIG. 345.—LOCOMOTIVE AND CAR—PIKE'S PEAK RACK RAILWAY.

The locomotives designed for rack traction on this particular system are equipped with three driving pinions set in advance of each other (Fig. miles in length, with grades as high as twenty-five per cent. One engine will push two cars, weighing 42,000 lbs. loaded. The average speed is five

miles an hour; on twenty-five per cent. grades it is three miles per hour, and on eight per cent. grades eight miles. The car seats are not tilted, but are so arranged as to give the passengers a level footing.

The braking arrangements on locomotives designed for this class of roads must necessarily be very efficient. Ordinary brakes are applied to the adhesion drivers; then there are brake disks on the crank shaft of the pinion mechanism, by means of which the pinions may be completely locked; and sometimes there is an auxiliary loose pinion with the brake disks on the trailing axle of the locomotive. The braking on down grades, however, is usually done by means of the steam cylinders, operated as air compressors, there being special provision for this purpose, or by separate air cylinders operated from one of the axles.

Sometimes locomotives are constructed on a combined system of rack and adhesion, where there is a succession of slight and steep grades. These have separate cylinders for the driving pinions and the adhesion drivers which are used alternately as the grades demand.

On lines of the combined system it is important that the rack rail be properly entered by the pinion without slackening the speed of the train. This is accomplished by laying down a special entering rack rail. This entering rail (Fig. 346) is about ten feet in length, and is hinged to the rack, and its other free end rests upon strong spiral springs. The teeth towards the free end gradually diminish in height, giving that end a wedge-shaped appearance, as seen in the figure. As the locomotive passes over the entering rail the pinion is turned by friction, and within a few feet a true interlocking of the teeth is secured, when steam is admitted to the extra pair of cylinders and the machine easily climbs the grades. This system, which combines an extensive range of gradients with safety and economy of operation, will doubtless prove a valuable addition to modern means of transportation.

Another type of rack rail known as the Agudio system is in operation near Torino, Italy. In this system a small wire rope, driven from a terminal station, after the manner of cable lines, is led over two sheaves attached to the side of the motor car, called a locomotor, and by means of reduction gear transmits power to two horizontal cog wheels, which embrace a central cog or rack rail, and propel the motor with sufficient power to push a train of several cars, on a grade which in places equals thirty-eight per cent. The cog rail in this case consists of a steel ribbon bent zig-zag in such a manner as to present teeth on each side. This is fastened by means of channel bars and bolts to a central beam. The motor is in a measure independent of the cable, and by means of friction clutches the train can be stopped or run backwards

CHAPTER VII.

ELEVATED ROADS.

In order to secure rapid transit for large cities it is necessary, usually, to put up with some inconvenience and many prejudices. A practical location must be allowed so that the road can be built at a moderate cost, and the public must consent to such cheap and sound plans as will make it reasonably certain that the enterprise will eventually pay a moderate return on the investment.

There are those who advocate the building and operating of the rapid transit lines by the municipal authorities, but, as this is opposed to the spirit of our institutions, private corporations must be allowed to undertake the work. This, however, should be done under the direction of a commission composed of the soundest, purest and most prudent citizens, aided by the leading officials of the city and the engineers of the various city departments.

Rapid transit seeks to substitute for a system of surface lines operated by animal or mechanical power a cheaper mode of transit, in connection with which speed and comfort shall be greatly increased. Whether such a road will pay or not depends upon the volume of business and the amount of capital invested. The character of the roads designated as rapid transit may be divided into three classes, viz., underground, depressed and elevated. Without going into particulars, it is generally conceded that there are more difficulties in the way of building and operating the two former and more objections to them than to the last named system. Underground and depressed roads for rapid transit are not unlike those constructed for ordinary steam traffic, and, as they are not likely to come into very general use in this country, we confine our attention to elevated structures, as involving fewer contingencies than other systems, and because the cost can be estimated beforehand with reasonable accuracy.

Many objections are urged against elevated structures because they are unsightly, noisy and affect the value of abutting property, but, the road once in successful operation, its appearance is seldom noticed, the noise (which is not a necessary adjunct) ceases to disturb, the increase in the value of suburban property more than balances the supposed damage to property along the line, while the increased facilities and comforts outnumber the discomforts. An elevated line may be built on masonry, on such portions as pass through blocks or over private property; but, generally, it should be an iron skeleton structure, and should be made as pleasing in appearance as possible, by tasteful design and appropriate ornamentation. There should be an adaptation of means to ends, but, as in most engineering works, there is no best plan to be applied everywhere and under all circumstances.

Real rapid transit on long lines where the traffic is heavy can only be obtained on a three or four track road, on one or two of which express trains can be run at a high rate of speed and which shall stop only at long intervals.

In wide streets there are two possible locations for elevated structures. The tracks may be close together over the centre of the roadway or they may be independent, one on each side of the street. The requirement that the posts for centre lines shall be located along the line of the curb involves the construction of a double set of girders, one along the street to carry the tracks and the other across the street to support the first set. This construction is much more expensive, depending upon the width of the street.

The span members of an elevated structure are usually of a uniform pattern throughout, but specially designed members are sometimes necessary. The expense will vary according to the designs

adopted. The plate girder construction is preferable for all spans under sixty feet, but for spans over sixty feet, up to one hundred, the lattice type of girder is usually employed, while the pin type is employed when the spans are above one hundred feet.

The successive steps in the construction of an elevated structure are about as follows :

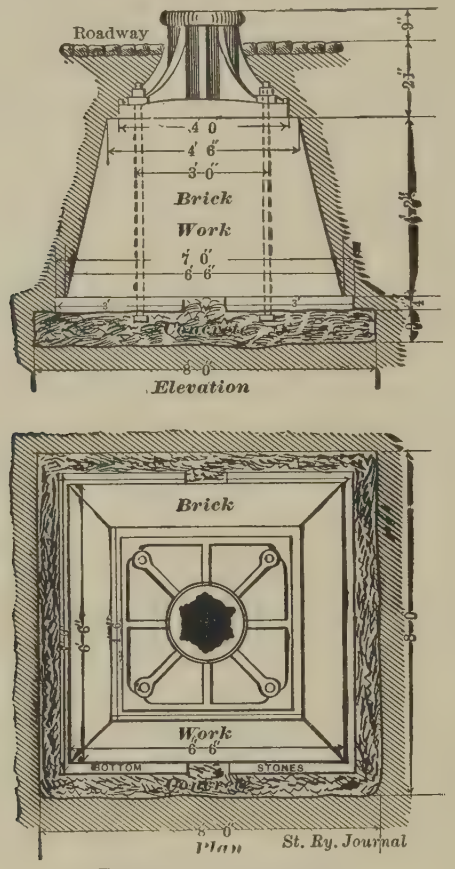


FIG. 347.—STREET PIER.

Preliminary survey, location of foundation piers, construction of foundations, erection of the iron structure, track structure and track laying and painting.

The survey should be made with the greatest care ; and notwithstanding the difficulties of doing this in crowded business streets, the requirements have in some cases been made that no errors greater than one inch in 1,000 ft. of horizontal measurement, and .005 ft. per one foot in elevation be allowed.

The first step is the adoption of a convenient base line that can be used till the final completion. Next, the longitudinal distances are measured, and this is best done with wooden rods of suitable length. Full stations every hundred feet, and sub-stations every twenty-five feet are thus located and marked. From these stations all obstacles, such as sewer basins, hydrants, manholes, lamp posts, sewer, gas and water mains, vaults, etc., are measured and mapped. The spacing and arrangement of the columns next follows, and then the grade and

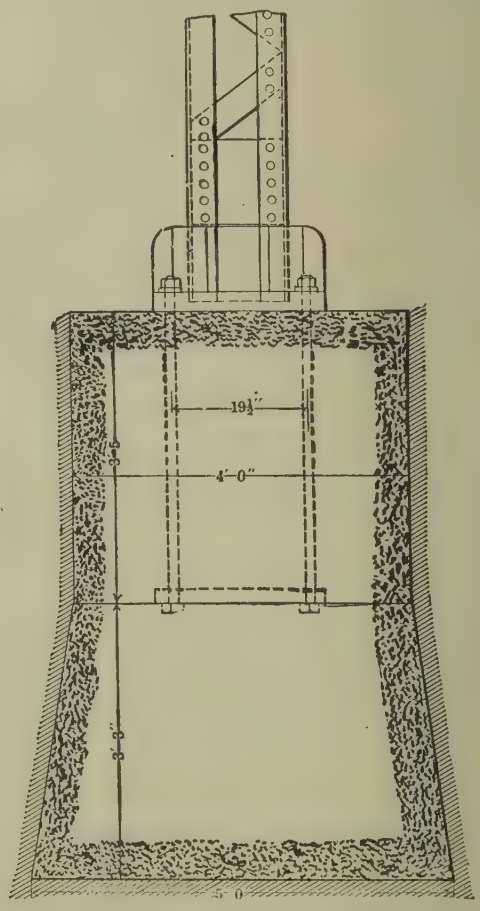


FIG. 348.—CONCRETE PIER.

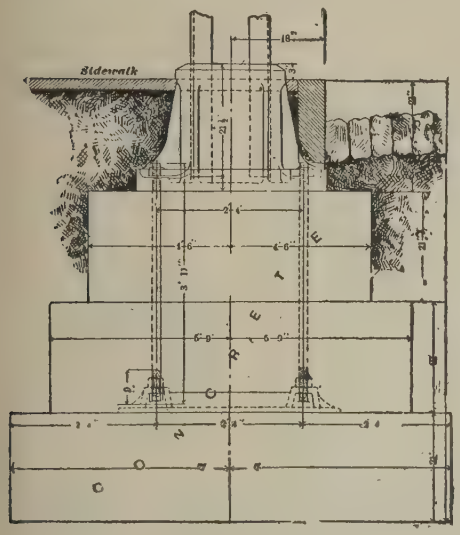
length of columns are determined. For the purposes of construction, bench marks 500 ft. apart are next established.

The following designs are all taken from lines actually in operation or being built, and will be found to embrace most of the conditions for safe, rapid and economical operation.

DETAILS OF CONSTRUCTION.

Fig. 347 is an elevation and plan of a standard street pier extensively adopted in the construction of elevated roads. In the construction pits are first opened about nine feet square and excavated

to a depth of seven feet or more, depending on the nature of the soil. If the soil formation is satisfactory, a layer of concrete eight feet square and nine inches thick is first laid down; before setting, pockets may be scooped in the surface to receive



ELEVATION

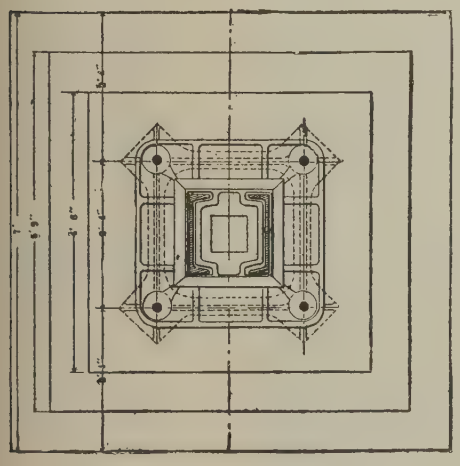


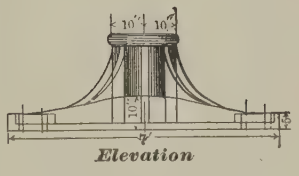
FIG. 349.—PLAN, STREET PIER.

subsequently the bolt washers and heads. On the top of the concrete are placed two stones five inches thick and 3 × 7 ft.; these stones serve as support for the brick pier and the purpose of anchorage for bolts.

The proportion of brick work is clearly shown in the figure, and for such a construction it requires about 7,000 bricks. The piers may be built entirely of concrete if preferred, as shown in Figs. 348 and 349.

One pattern of base casting is shown in Fig. 350, which is bolted to the foundation, as indicated in Fig. 347.

A standard sidewalk pier is illustrated in Fig. 351, and differs in depth from the street pier.



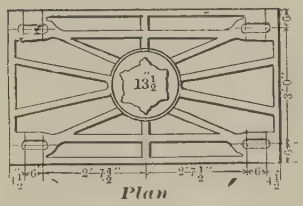
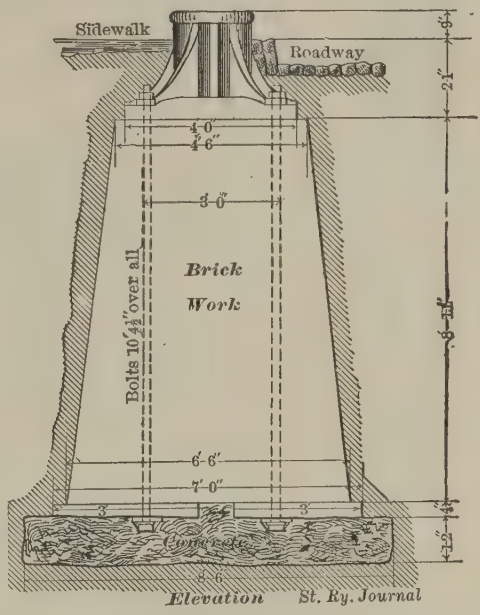


FIG. 350.



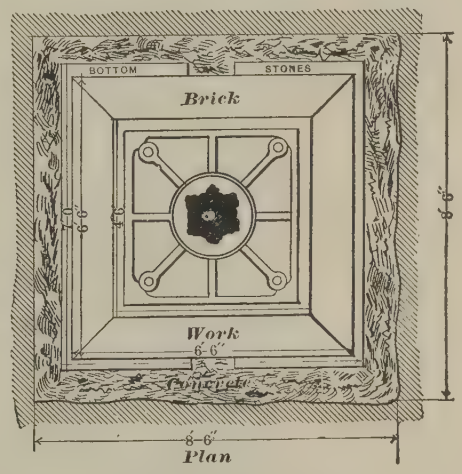


FIG. 351.—SIDEWALK PIER.

Piers of special construction are sometimes required when subterranean obstacles are encountered, such as water and gas mains and sewers, or when the foundation is too soft to sustain the weight. Fig. 352 shows two elevations of a specially constructed pier where obstacles were met with, and Fig. 353 a construction upon a pile foundation rendered necessary on account of soft foundation. In the specifications for building the above street piers the cement was required to be

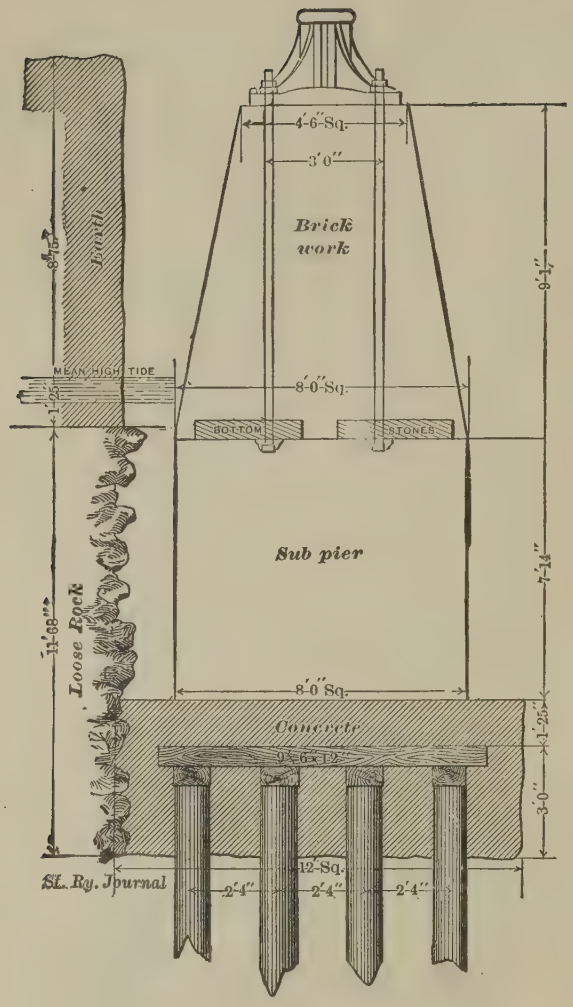


FIG. 353.—PIER WITH PILE FOUNDATION.

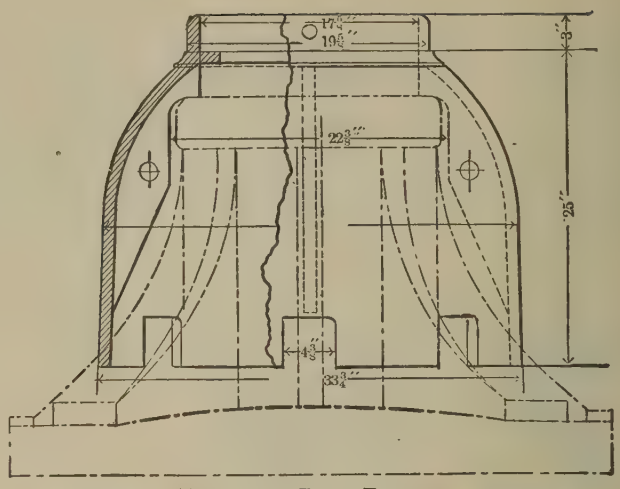


FIG. 354.—BASE FENDER.

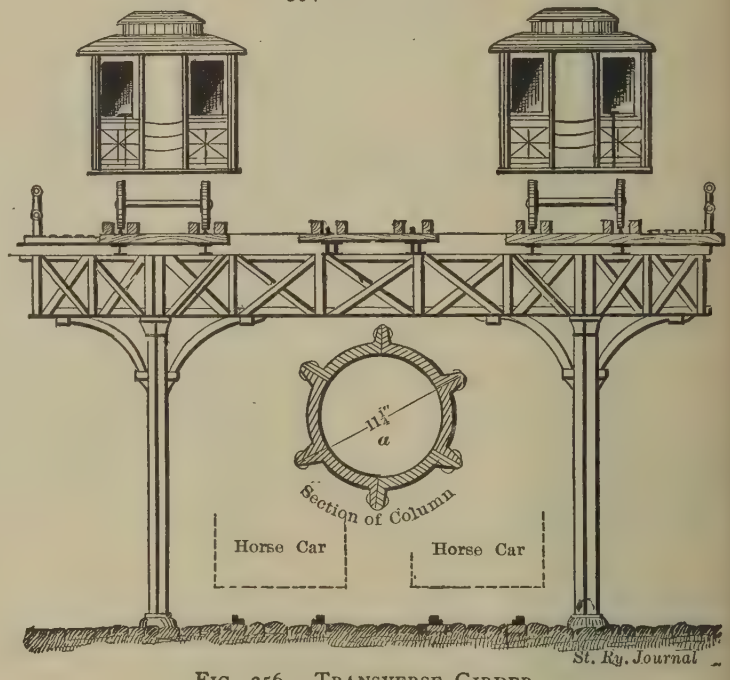


FIG. 356.—TRANSVERSE GIRDER.

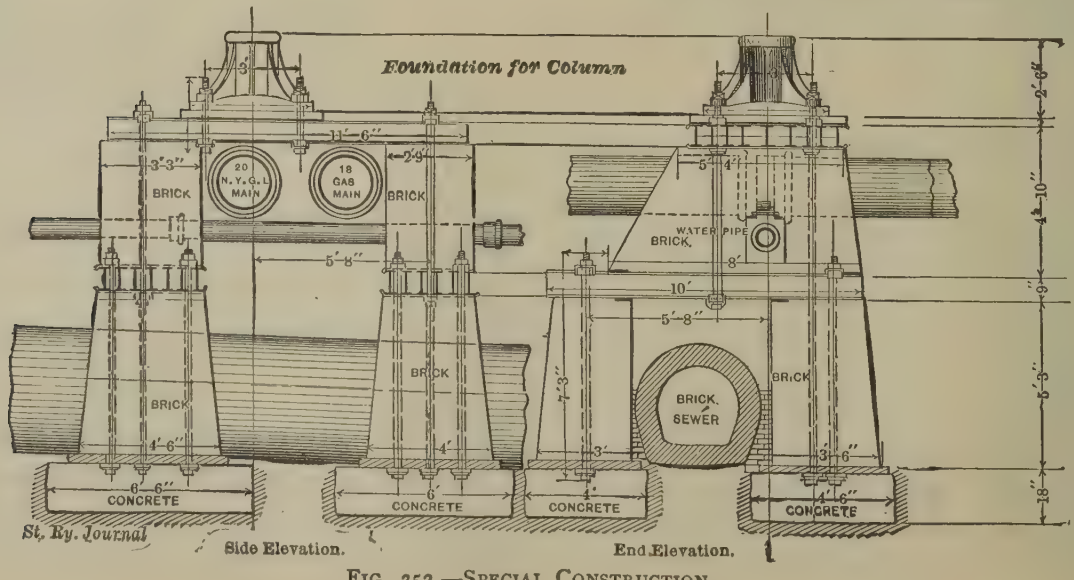


FIG. 352.—SPECIAL CONSTRUCTION.

capable of resisting a tensile strain of fifty pounds to the square inch, after thirty minutes exposure in air or twenty-four hours immersion in water.

Fig. 354 illustrates a cast iron, bell-shaped fender, designed to embrace the base and protect the columns from being struck by the wheel hubs of passing vehicles. The space between the shell of the fender and the base casting is filled with cement mortar. In the figure the base and column are shown by the dotted lines.

The foundation piers being in place, the next step is the erection of the columns and placing them in the base castings. This may be accomplished by means of a derrick, wagon and horse power, or by a derrick on the structure as shown below. With seven men and a team of horses from ten to forty columns can be set up in a day. The columns are held temporarily in place by inserting iron wedges inside the rim of the base casting, and the space between the barrel of the bare casting and the column is caulked with oakum to keep out the water prior to using a cast iron cement.

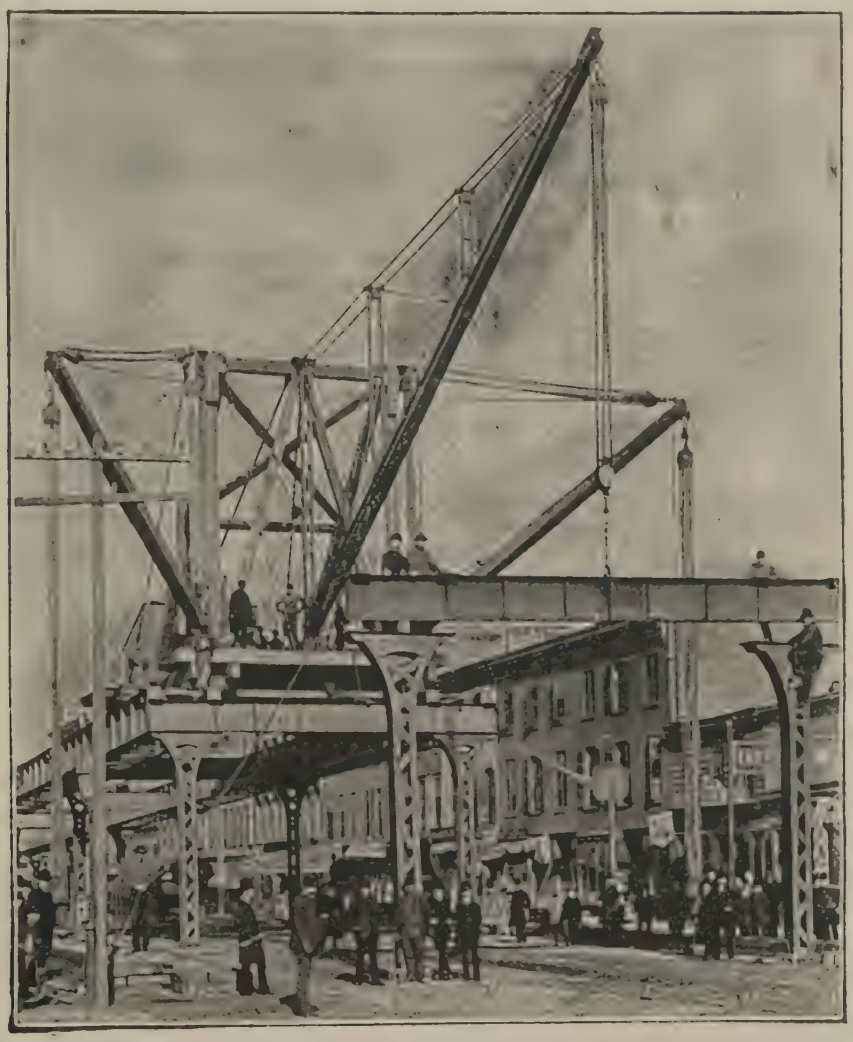


Fig. 355.—Travelling Derrick.

The girders may be raised by a travelling derrick mounted on the structure and operated by steam power (Fig. 355).

The girders being in place, the braces adjusted and riveted, the columns are carefully plumbed and are held by jack screws and braces until a cast iron cement has been substituted for the oakum at the base.

A cement that will be as strong as or stronger than the iron itself is made of the following: One ounce of sal-ammoniac to one gallon of water. With a minimum amount of the solution, cast iron turnings or borings, clean and free from rust, are mixed and left standing for half an hour to "warm up." The mixture is then dropped in layers of one-eighth to one half an inch and thoroughly tamped. In forty-eight hours the cement becomes as hard as the iron.

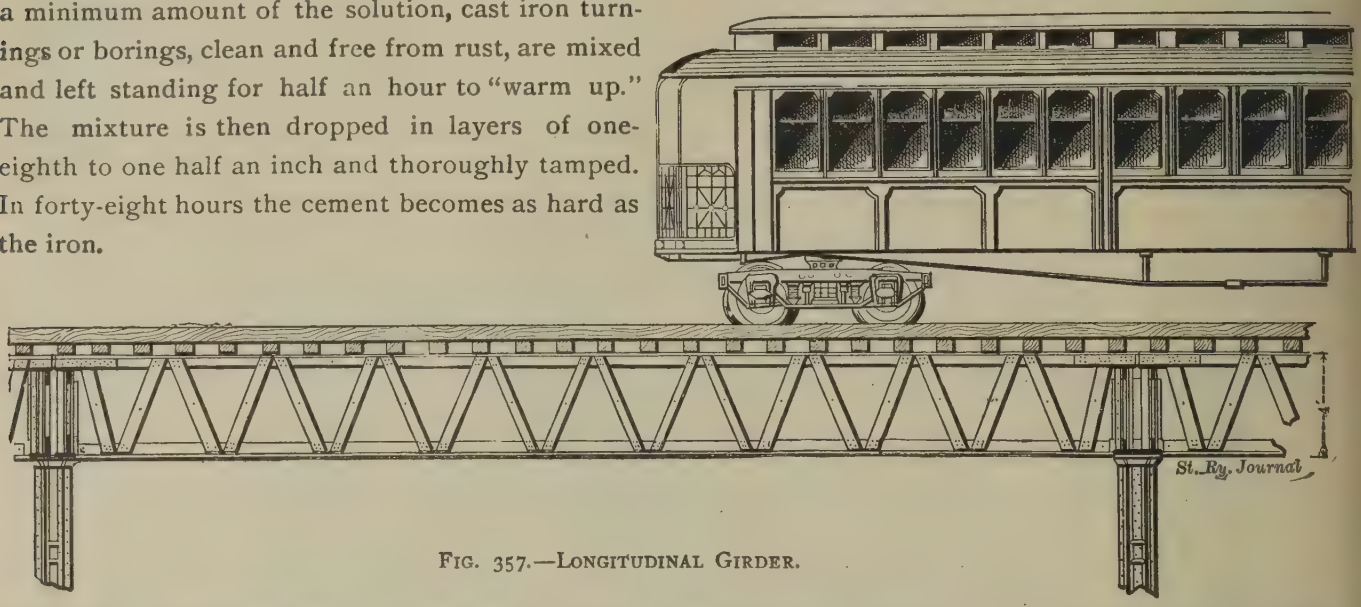


FIG. 357.—LONGITUDINAL GIRDER.

Fig. 356 is an elevation of a transverse girder with columns located in the street, double braced and directly under the tracks. Section of the six-segment, wrought iron column is shown at *a*. This construction provides for four tracks if necessary. Platform for employes and posts for guard rails are clearly indicated, as are also the guard timbers each side the rails.

In this construction it will be noted that the longitudinal girders (Fig. 357) are of the deck system, with the upper chords resting upon the top chords of the transverse girders. The former are of the plain triangular type, four feet deep, and are set in pairs under each track, five feet between centres. They weigh about 130 lbs. per lineal foot. The

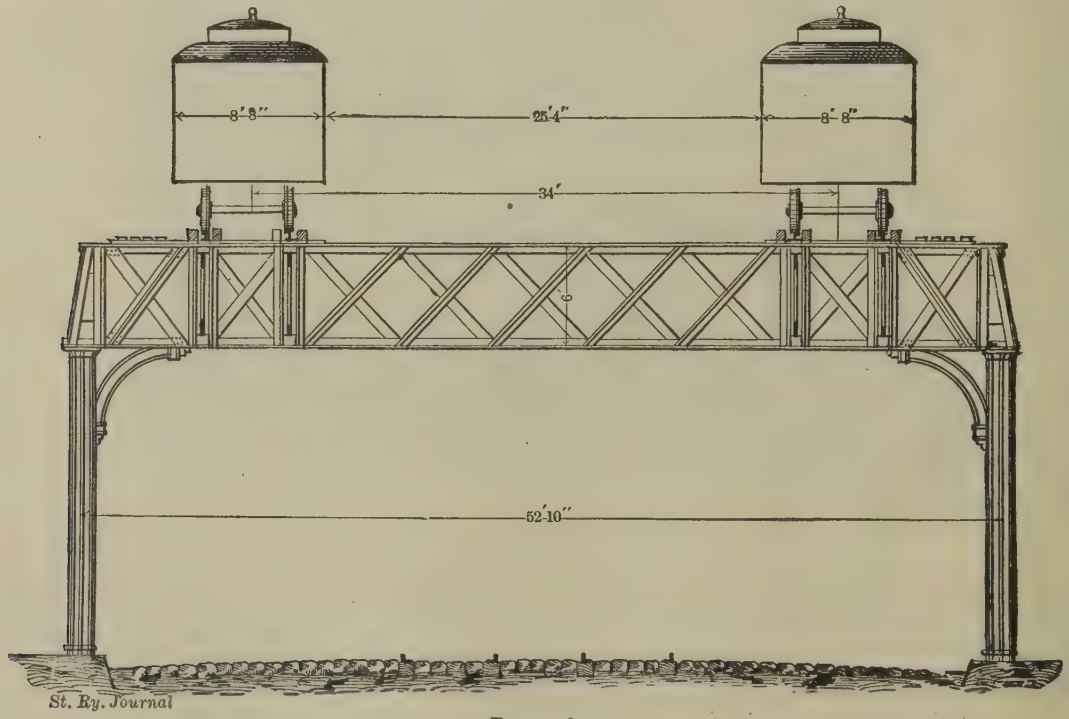


FIG. 358.

ansverse girders have a double triangular system nd weigh 200 lbs. per lineal foot.

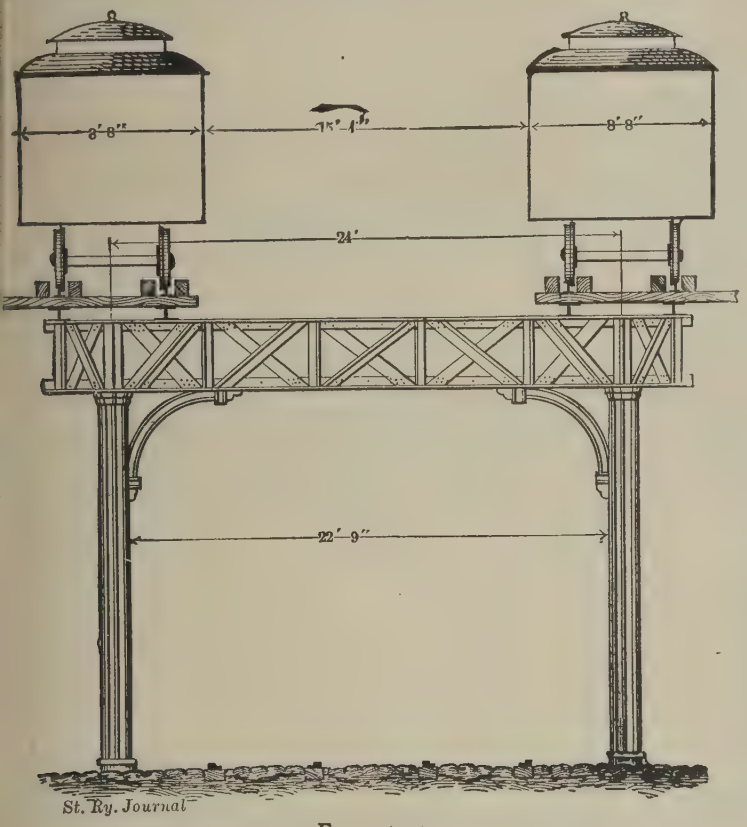


FIG. 359.

Fig. 358 illustrates another form of transverse girder with the sustaining columns located on the curb line. Provision is made for framing in the longitudinal girder at points directly under the rails.

In Fig. 359 is shown a more compact construction, having the columns in the street, and with single braces.

Fig. 360 illustrates columns located in the street and made with channels latticed together, having flanging tops, upon which the longitudinal girder (Fig 361) rests. The transverse girder is in the form of a light arch, and serves only to brace the posts. The lattice type of girder is made mostly of le iron and is illustrated in the last figure. This particular construction was strengthened, after being put in service, by the addition of the flat braces which pass through the spaces between the channel braces.

A one-legged structure, similar to the last, is shown in Fig. 362. Here, it will be observed, the transverse girder is omitted, and the columns are maintained in a perpendicular position by the stability of the base.

In the single column structure it is necessary to anchor the column to a very stable foundation to provide against side oscillation. Where the streets are narrow the columns may be placed inside the curb line and surmounted by double deck trestle. A design of this kind is cheaply constructed and may be arranged to shade the street but little.

A reinforced transverse girder is illustrated in Fig. 363; and here again we find the posts located on the curb line.

In Fig. 364 we have a novel construction; the posts are made of riveted plate; the transverse girder is of the plate type, and is supported at the side of the columns which extend above the rails, and with the longitudinal girder, shown in Fig. 365, serve as guards to prevent the possibility of

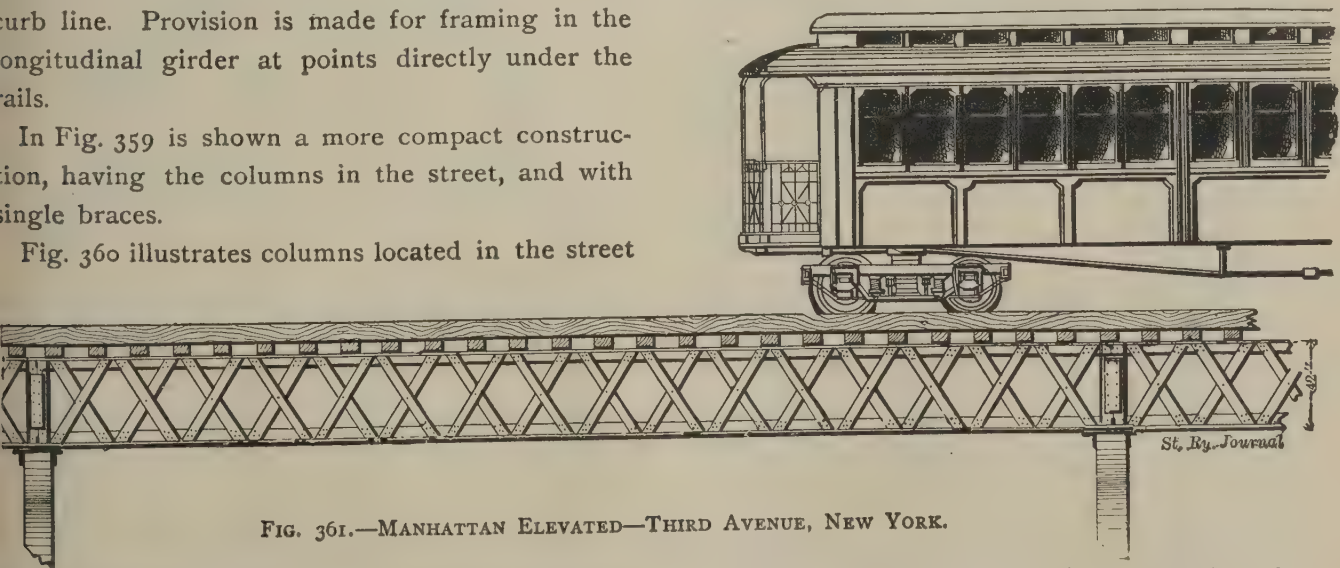


FIG. 361.—MANHATTAN ELEVATED—THIRD AVENUE, NEW YORK.

the car falling to the street in case it should become derailed.

Columns of unusual length are sometimes required to keep the line up to grade where it leads over depressions in the surface. An unusually high construction is shown in Figs. 366 and 367. The latter is taken from a photograph of the construction on Eighth Avenue, above 110th Street, New York.

A plate girder construction upon stone piers is

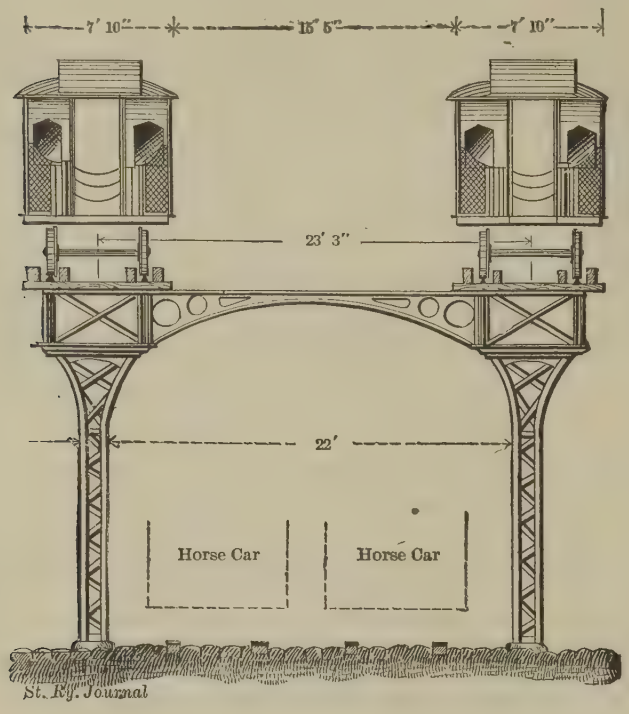


FIG. 360.—MANHATTAN ELEVATED—THIRD AVENUE.

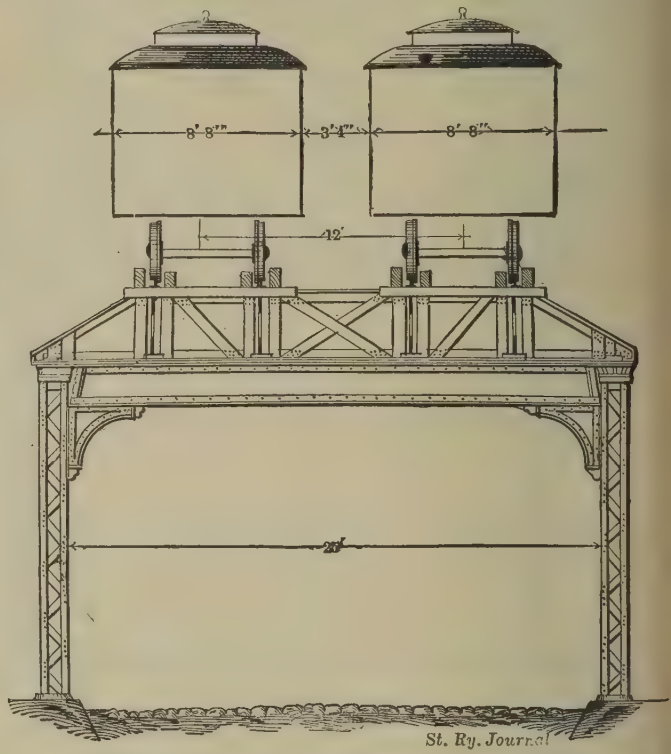


FIG. 363.—REINFORCED TRANSVERSE GIRDER.

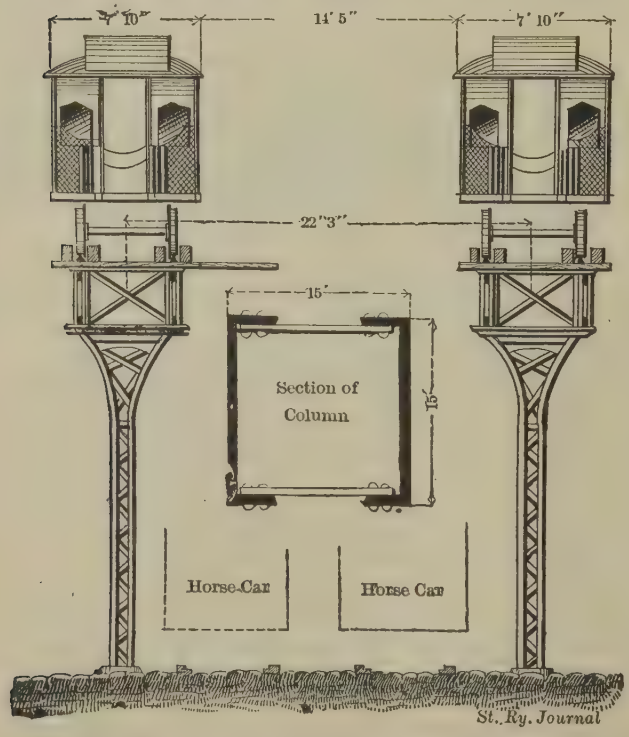


FIG. 362.—MANHATTAN ELEVATED—BOWERY.

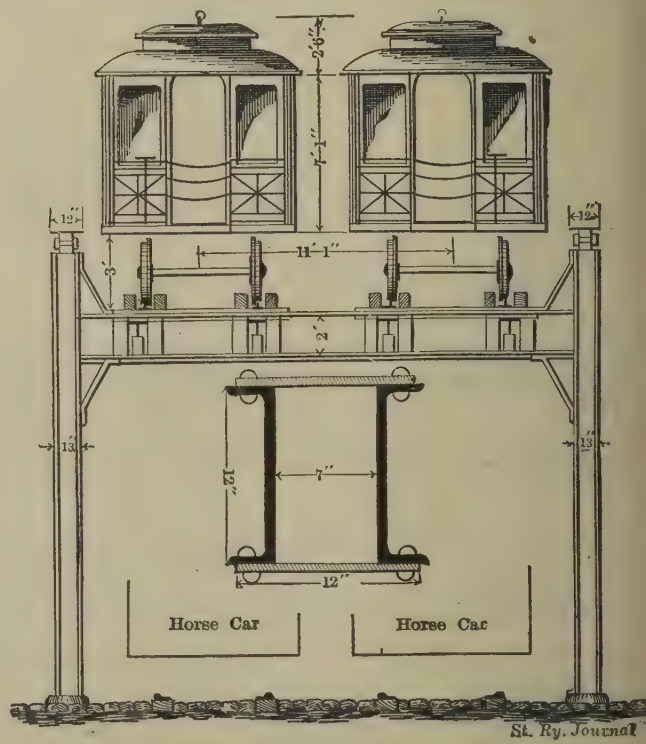


FIG. 364.—MANHATTAN ELEVATED—SIXTH AVENUE.

illustrated by Fig. 368. This design is adapted for lines that are built upon private property. The same figure shows the position and design of a station, and also that of a bridge for a street crossing.

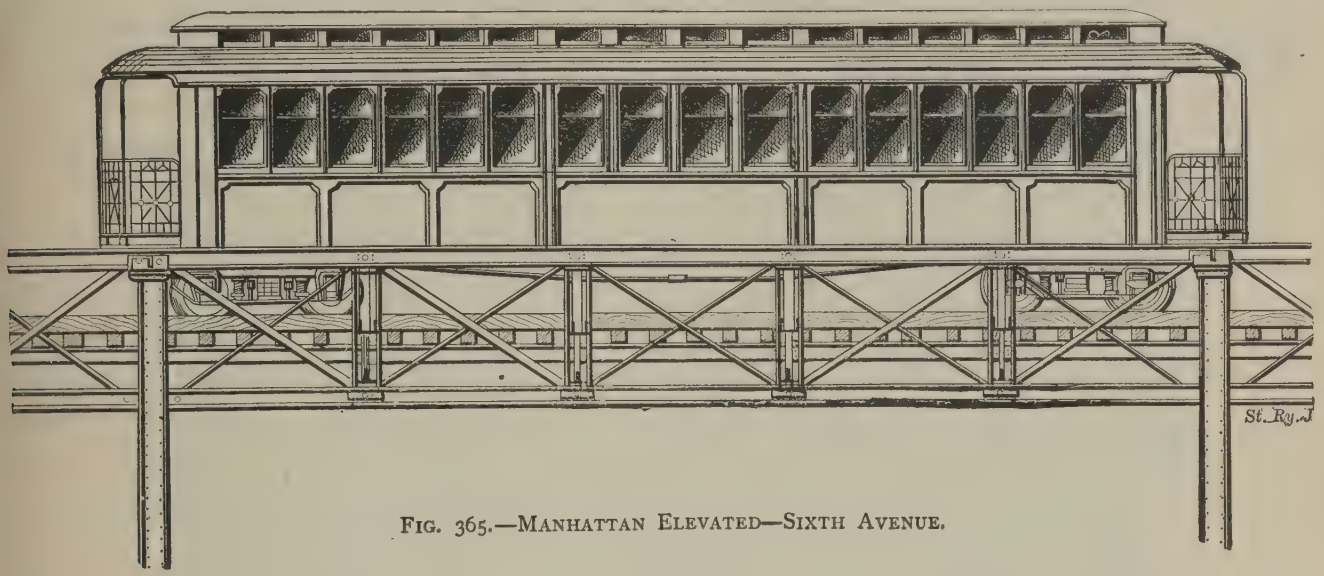


FIG. 365.—MANHATTAN ELEVATED—SIXTH AVENUE.

Figs. 369, 370, 371, 372 and 373, are typical designs which are self explanatory, and do not need a description. Figs. 374 and 375 illustrate exterior

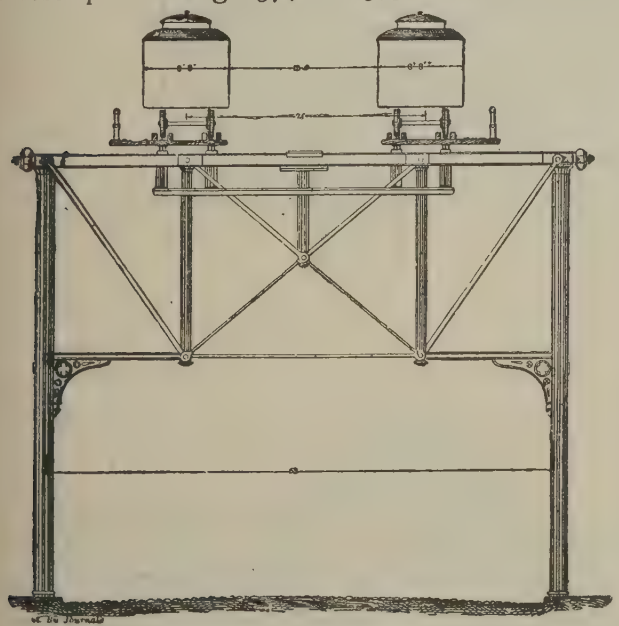


FIG. 366.

and approaches of stations on the lines of the New York elevated roads.

We come next (Fig. 376) to quite a different construction and one that has been followed by one of the lines in Chicago. The foundation pier, columns and general elevation are shown in the figure. The construction in this particular case being over private property, the columns are placed quite close together. Fig. 377 is an elevation of one-half of the longitudinal girder which, it will be seen, has a plate web with angle iron chords. A plan of the track for the same construction is shown in Fig. 378.

Fig. 379 is an illustration of light construction for moderate traffic, and differs in some respects from the construction previously described. The track rails rest on wooden blocks supported by the bent U plate between the channel bars, so that guard timbers are not required.

Fig. 380 illustrates a cross section at a station in which the dimensions are clearly shown, and in Fig. 381 we have a side elevation of the passenger platform, and in Fig. 382 a plan of the same. On entering the station passengers go around the ticket office at C, thence into the waiting room, and by a central stairway to the platform, as indicated by the arrows. Only one ticket collector is required, and he is stationed at D, and after passing the cancelling box, the passengers turn in both directions up the flight of stairs to the platforms, according to the directions in which they wish to go. Fuller details of station and line construction are shown in Figs. 383 and 384.

Fig. 385 illustrates a distinct type of column and girder, with the former located on the curb line. On the particular line having the above construc-

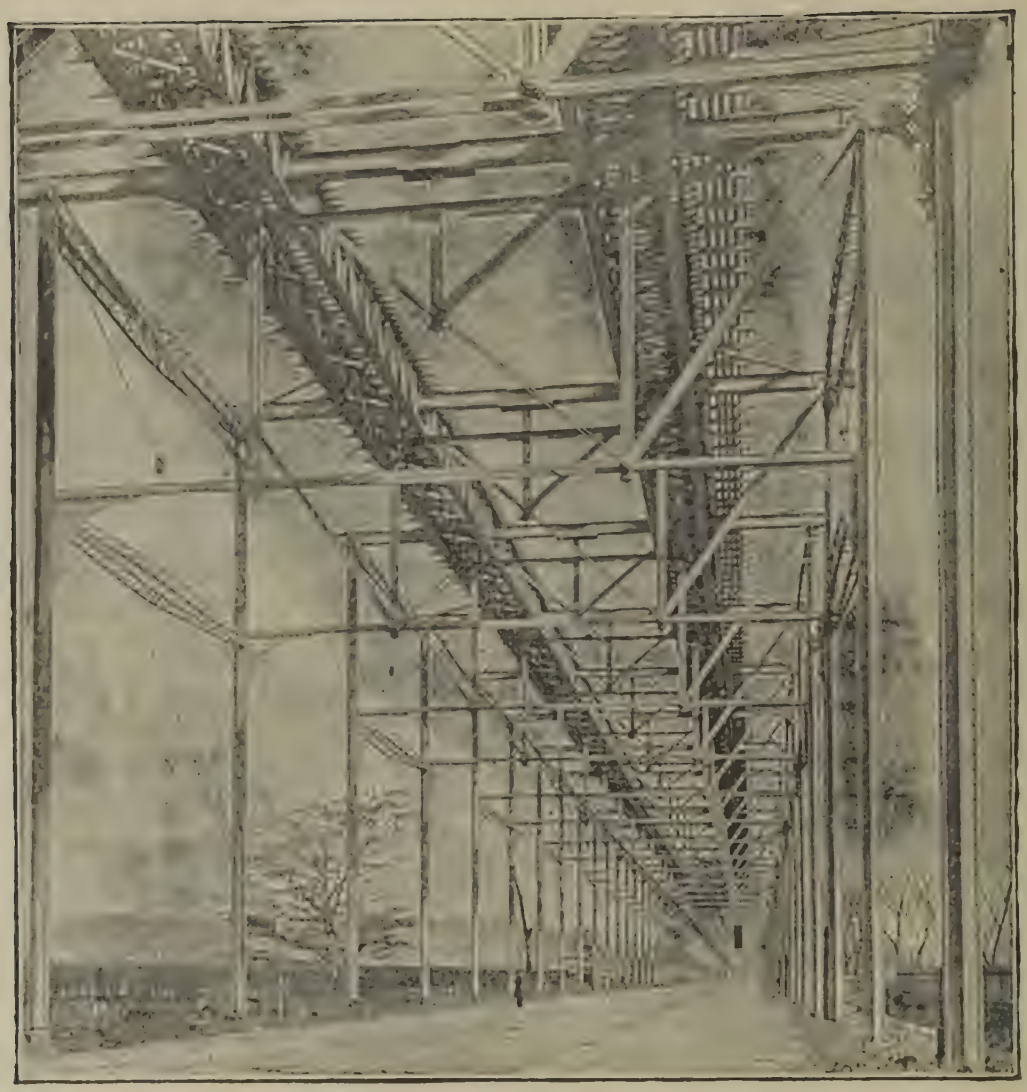


FIG. 367.—MANHATTAN ELEVATED—EIGHTH AVENUE AND 111TH STREET.

FIG. 368.—MANHATTAN ELEVATED—SUBURBAN LINE.

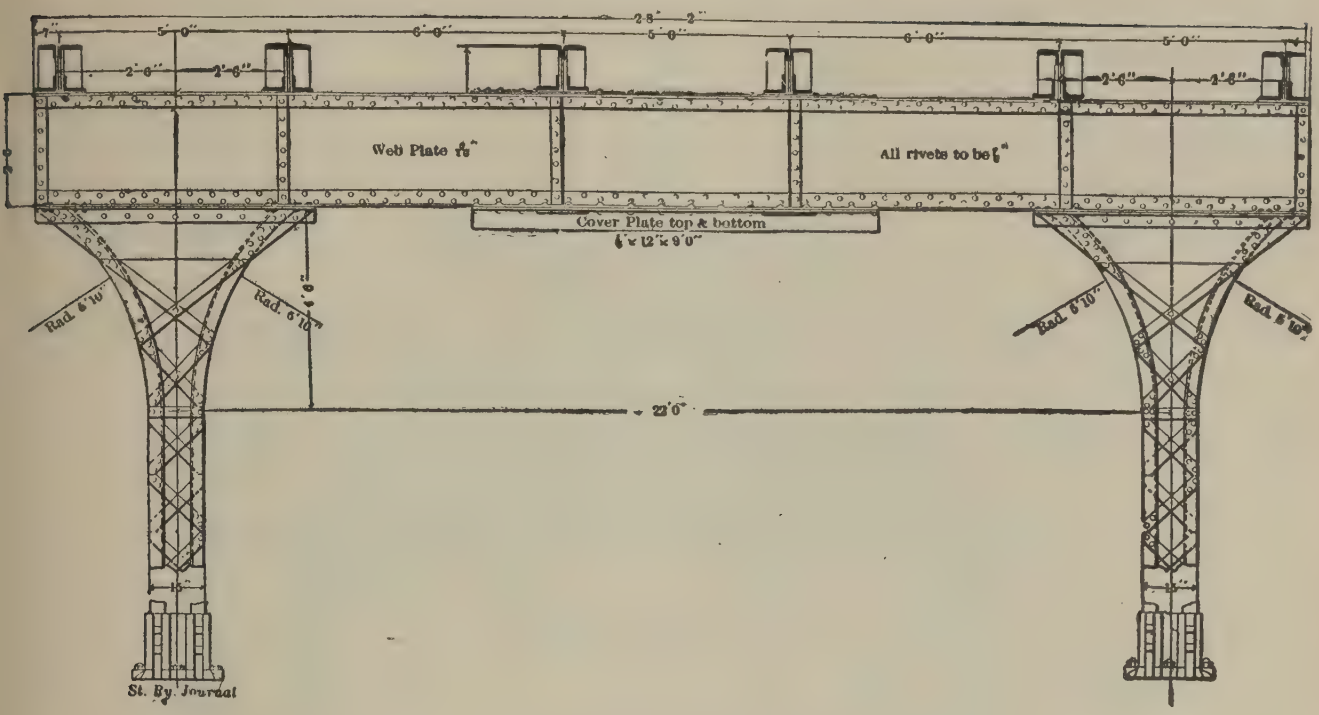


FIG. 370.—BROOKLYN ELEVATED.

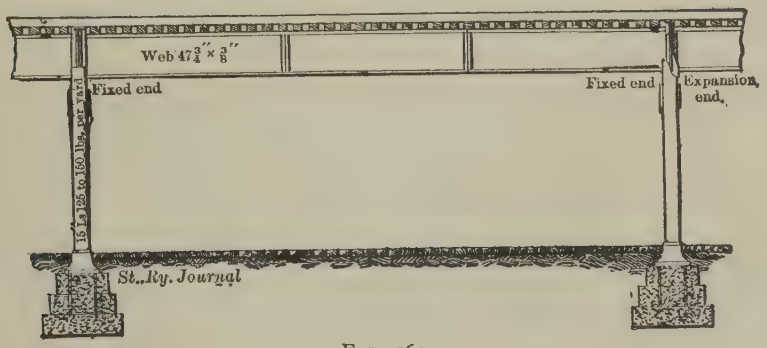


FIG. 369.

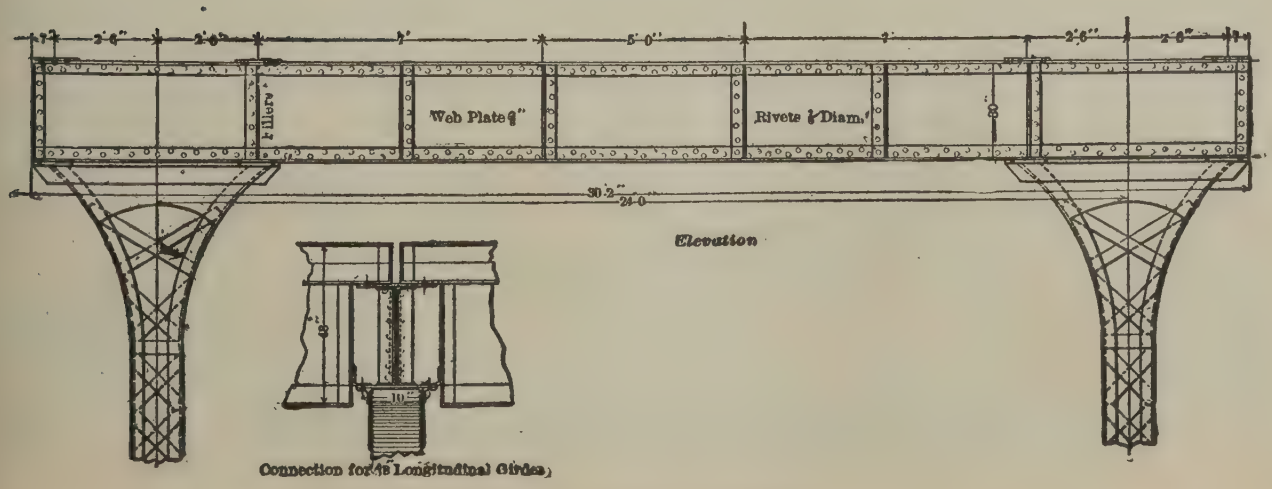


FIG. 371.—BROOKLYN ELEVATED.

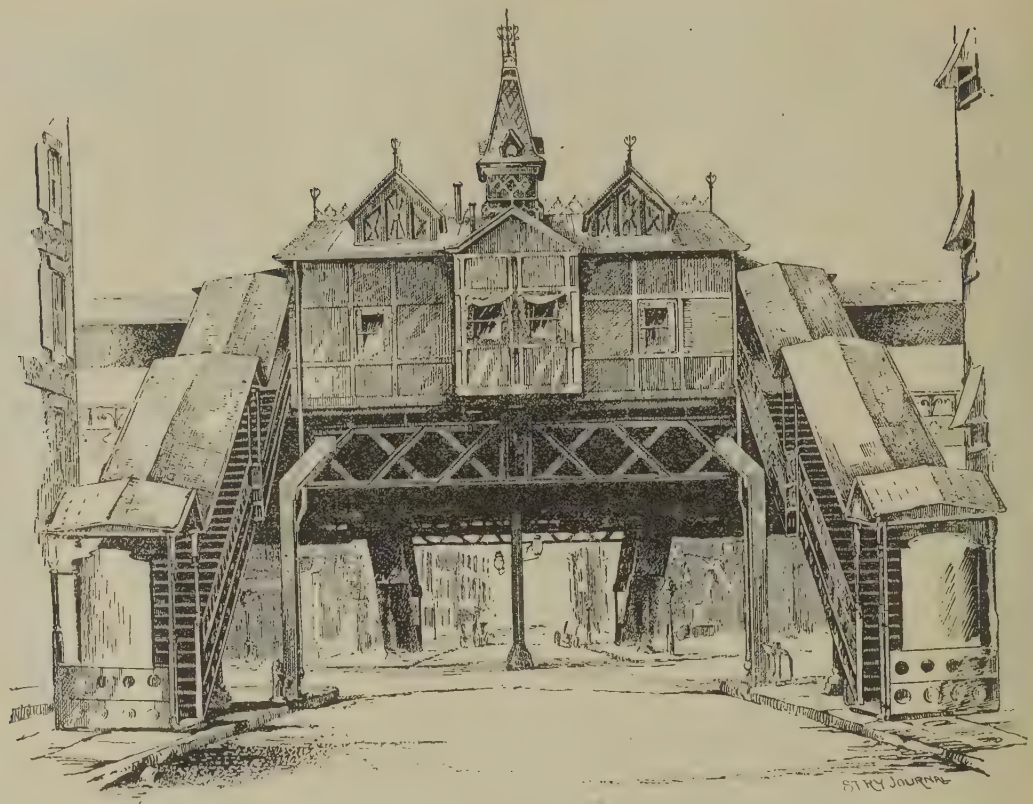
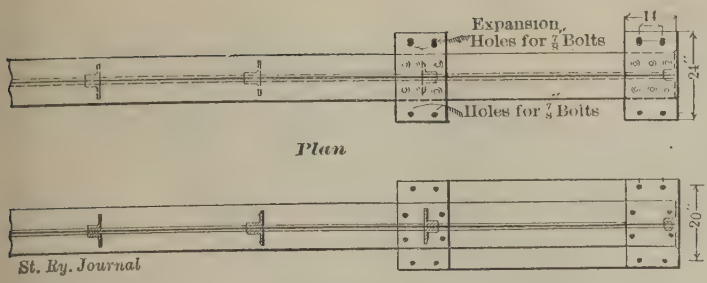


FIG. 374.—APPEARANCE OF ELEVATED STATION FROM CROSS STREET.

FIG. 373.—STATION AT 33D STREET—SIXTH AVENUE ELEVATED ROAD, NEW YORK.



375.— Section of Top and Bottom Chords of Fig. 371.

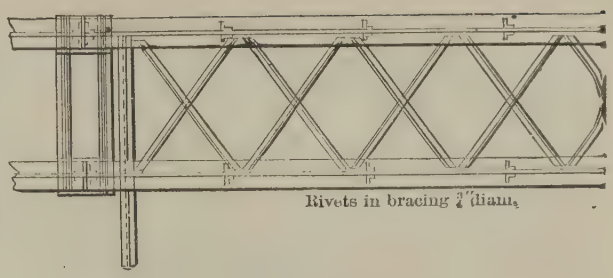


Fig. 378.—Plan of Track.

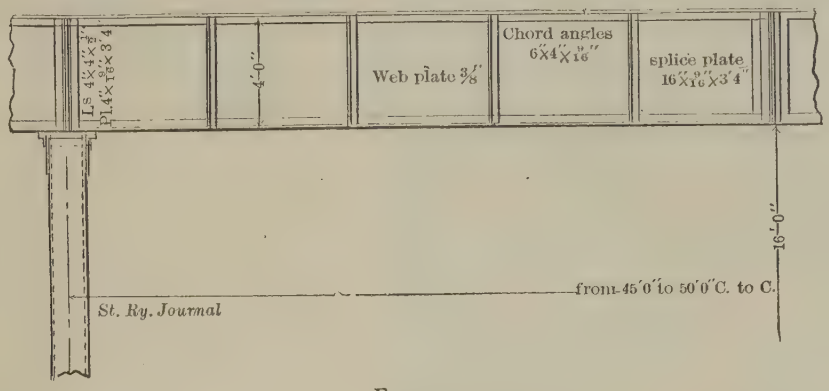


Fig. 377.

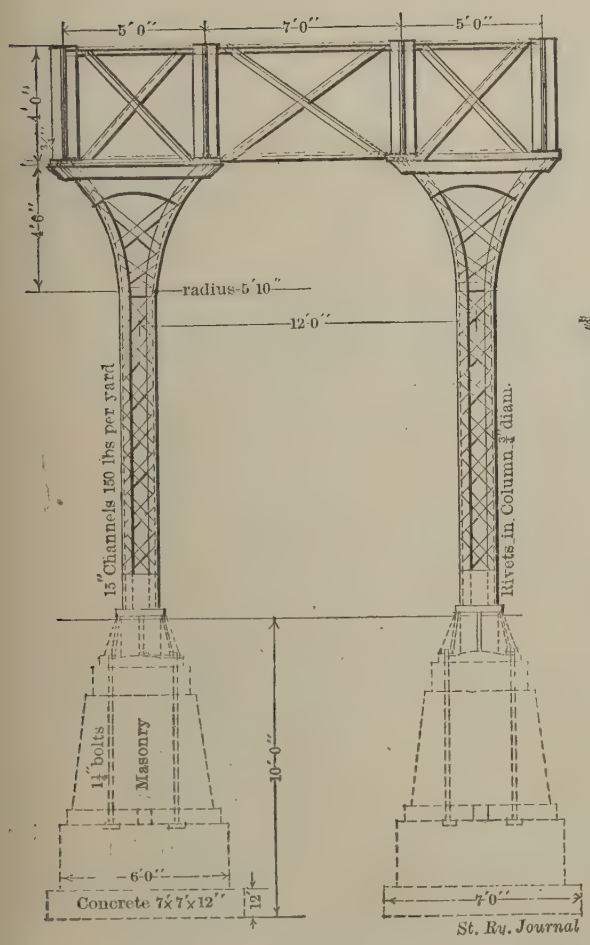


Fig. 376.—Alley Road—Chicago.

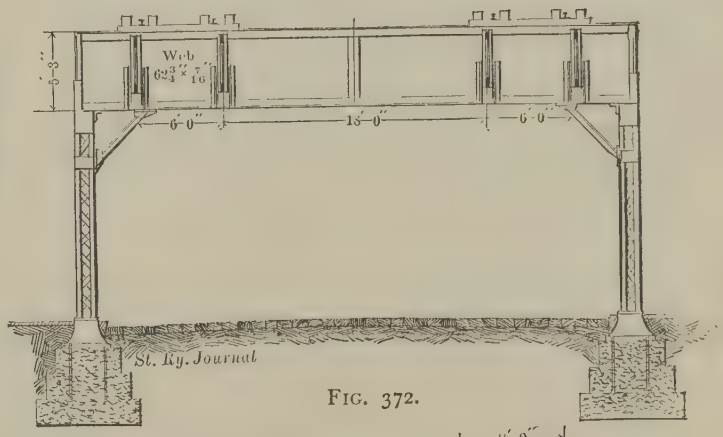


Fig. 372.

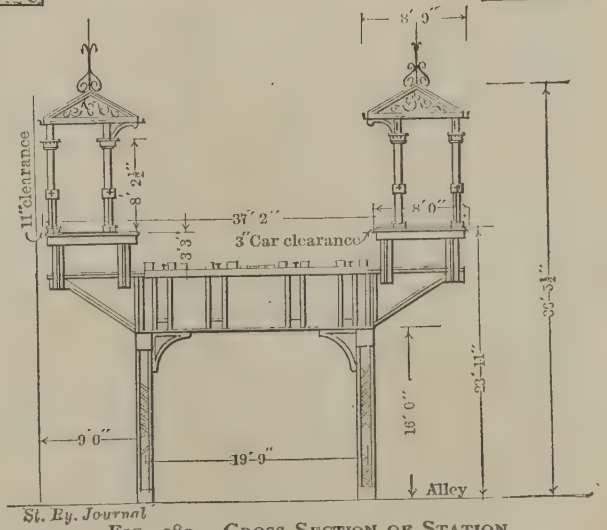


Fig. 380.—Cross Section of Station.

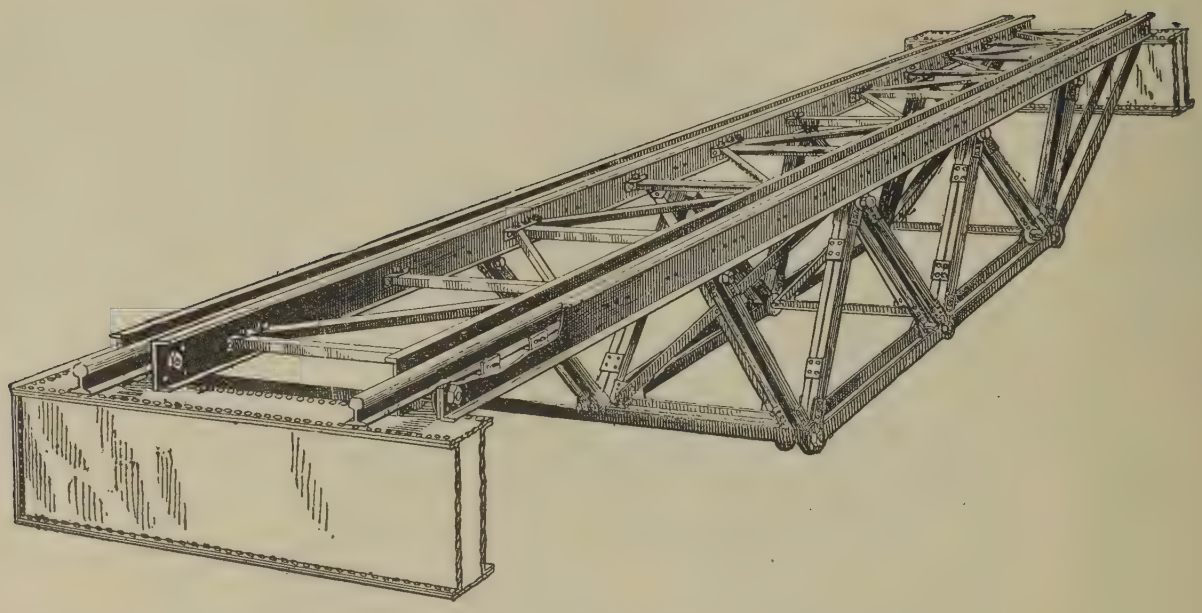


FIG. 379.—KANSAS CITY ELEVATED ROAD CONSTRUCTION.

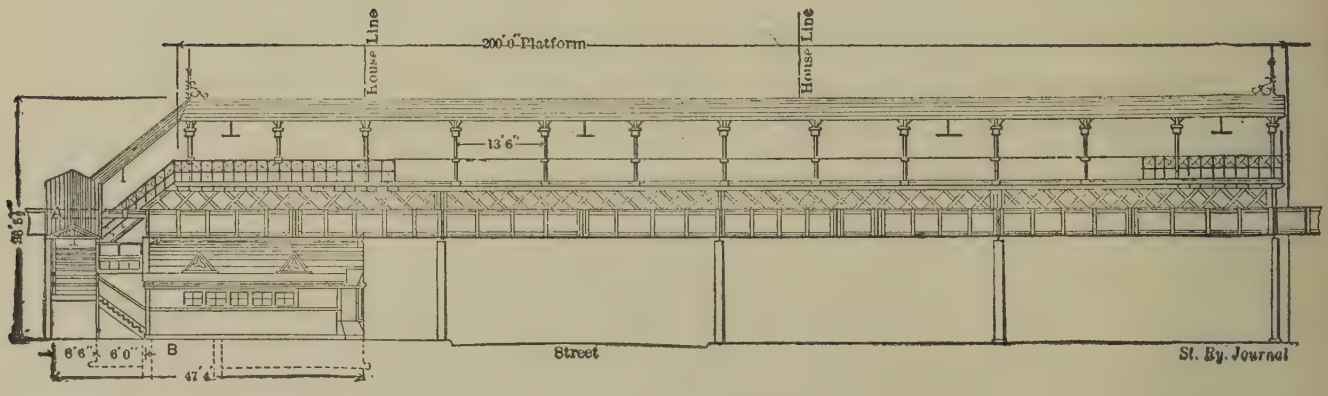


FIG. 381.—SIDE ELEVATION PLATFORM OF FIG. 380.

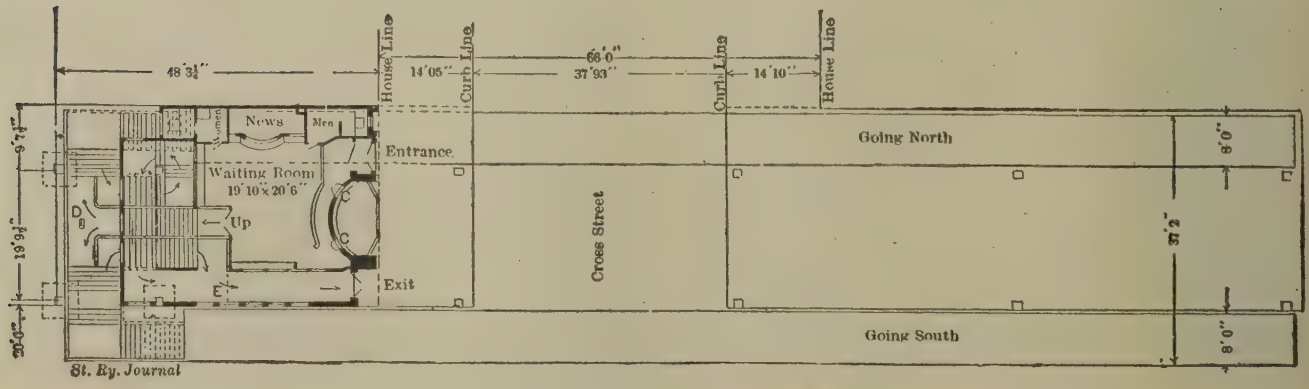


FIG. 382.—PLAN OF STATION PLATFORM OF FIG. 380.

tion the stations are built in the middle of the block, in buildings owned by the company, leaving the sidewalks entirely free.

In order that a better idea may be formed of the material and structure, illustrated in Fig. 285, we make the following extracts from the general specifications, upon which the contract for building this particular line was based.

"The structure is of wrought iron posts and girders; the posts have a horizontal section of 14 × 15 ins., and are made by two channels fifteen inches wide, connected by lattice bars. The channels in the posts, designed to support girders of fifty feet span, weigh 139 lbs. per yard, and for the fifty-six feet spans 148 lbs. per yard.

"Provision is made for the expansion and contraction of the longitudinal girders to the amount of three-quarters of an inch, by leaving one end free to move, the other end being riveted to the cross girder. The clear span of the girders ranges from forty-five to sixty feet. The cross girders have upper and lower chords and web members, riveted up of plates and angles, and have a span from forty

Fig. 384.—South Side Elevated Road—Chicago.

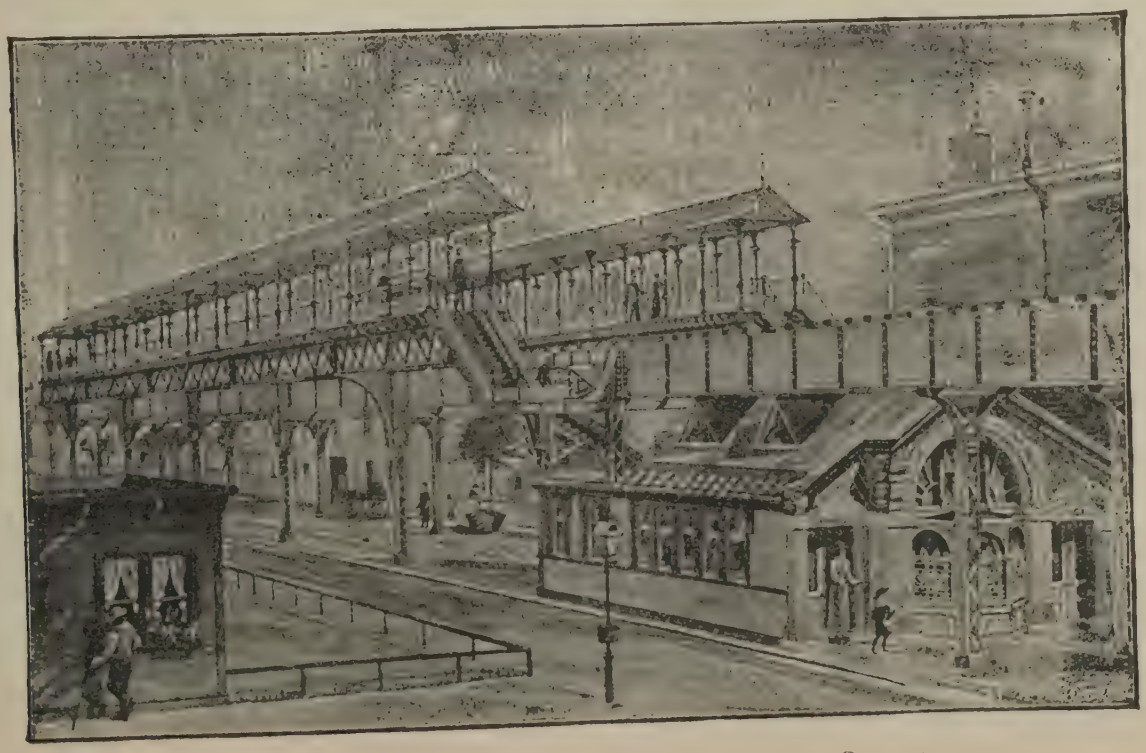


Fig. 383.—Station—South Side Elevated Railroad, Chicago.

to fifty-six feet, and weigh from 60,431 lbs. to 79,404 lbs.

"The web plates of the cross girders are seventy-one and three-quarters inches square, and vary in thickness from seven-sixteenths to nine-sixteenths

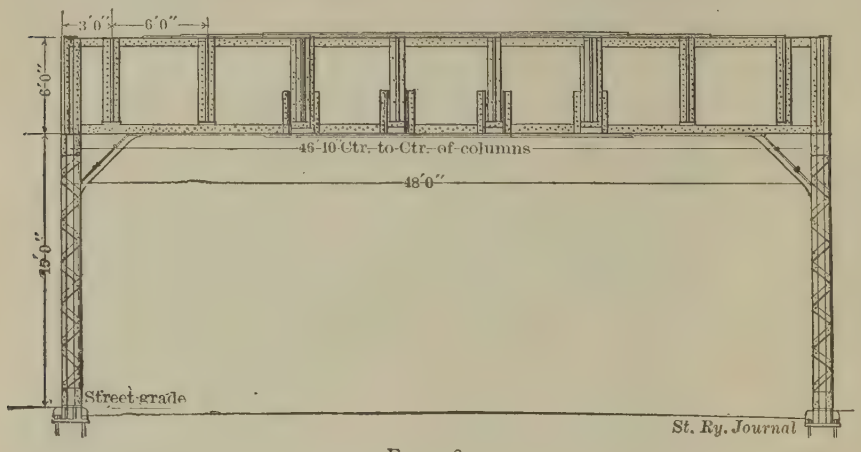


FIG. 385.

of an inch, the angles 6 ins. × 6 ins. × ⅞ in. Seats for longitudinal girders for two tracks are riveted to the cross girder, and holes for similar seats for two additional tracks are punched and covered with plates, till such time as the additions are made. The longitudinal girders are generally similar to the transverse girders. The longitudinal flange plates and the angle bars extend without joints from end to end of the girders.

"The cross girders and columns are braced by knee pieces of 6 ins. × 6 ins. × ⅞ in. angles, riveted to the columns and bolted to the girder.

"Iron of an elastic limit of not less than 26,000 lbs. per square inch is required.

"As far as possible all riveting is by machine. No hand driven rivets, excluding seven-eighths of an inch in diameter, are allowed."

Specifications for the structure, illustrated in Figs. 376 and 377, contain among others the following provisions: "Rivets and bolts, connecting parts of any members, must be spaced so that the shearing strain per square inch does not exceed 7,500 lbs., or three-fourths of the allowed tension strain per square inch on the member. Iron in web plate not to have a greater shearing strain than 4,000 lbs. per square inch; no web less than three-eighths of an inch thick. All wrought iron must have an elastic limit of not less than 26,000 lbs. per quare inch and be tough, fibrous and uniform in character. Full sized pieces of flat, round or square iron, not over four and a half inches in sectional area, shall have an ultimate strength of 50,000 lbs. per square inch, and stretch twelve and a half per cent. of their length. Tested in specimens of uniform sectional area of at least one-half square inch for a distance of ten inches, must show an ultimate strength of 50,000 lbs. per square inch and stretch eighteen per cent. in eight inches. All iron for tension to bend to an angle of ninety degrees cold, around a curve whose diameter is not over twice its own thickness, without cracking. One specimen in three to bend 180 degs. Nicked on one side and bent by a blow from a sledge, the fracture to be nearly all fibrous, with but few crystalline spots. Angle, plate and shaped iron to bend cold to ninety degrees around a curve whose diameter is not over three times the thickness." The above table gives data of dimensions, strains and movements.

Longitudinal Span C to C of Supports.	Maximum Bending Moment per Track Combined D and L Loads.	Depth of Girders.	Max. Chord Strain Combined L & D Loads.	Allowed Stress per sq. in.	Composition of Chords; Angles.	Equiv't Weight per lineal ft. per Girder.	Max. Shear in Web.	Thickness of Web.	Equiv't Distr. Load.
35 ft. to 40 ft.	484,195 ft. lbs.	42 in.	73,362	9,000 lbs	6 in. × 4 in. × $\frac{7}{16}$ in.	1,210 lbs.	24,200	⅜ in.	48,400
40 ft. to 45 ft.	586,655 ft. lbs.	48 in.	74,441	" "	6 in. × 4 in. × $\frac{7}{16}$ in.	1,158 lbs.	26,055	⅜ in.	52,110
45 ft. to 50 ft.	701,765 ft. lbs.	48 in.	89,969	" "	6 in. × 4 in. × $\frac{9}{16}$ in.	1,122 lbs.	27,550	⅜ in.	55,100
50 ft. to 55 ft.	838,677 ft. lbs.	48 in.	107,522	" "	6 in. × 4 in. × $\frac{11}{16}$ in.	1,109 lbs.	30,497	⅜ in.	60,995
55 ft. to 60 ft.	987,146 ft. lbs.	54 in.	114,784	" "	6 in. × 6 in. × $\frac{9}{16}$ in.	1,096 lbs.	32,880	$\frac{7}{16}$ in.	65,700
60 ft. to 65 ft.	1,116,243 ft. lbs.	54 in.	129,795	" "	6 in. × 6 in. × $\frac{11}{16}$ in.	1,056 lbs.	34,320	$\frac{7}{16}$ in.	68,640

TRACKS.

The next step is to provide the track foundation and to place the rails (Figs. 386 and 387). The

FIG. 386.—ORIGINAL TRACK CONSTRUCTION.

former illustrates the original form of construction employed on the New York elevated roads and the latter the more recent practice of the same lines. The track material consists, usually, of yel-

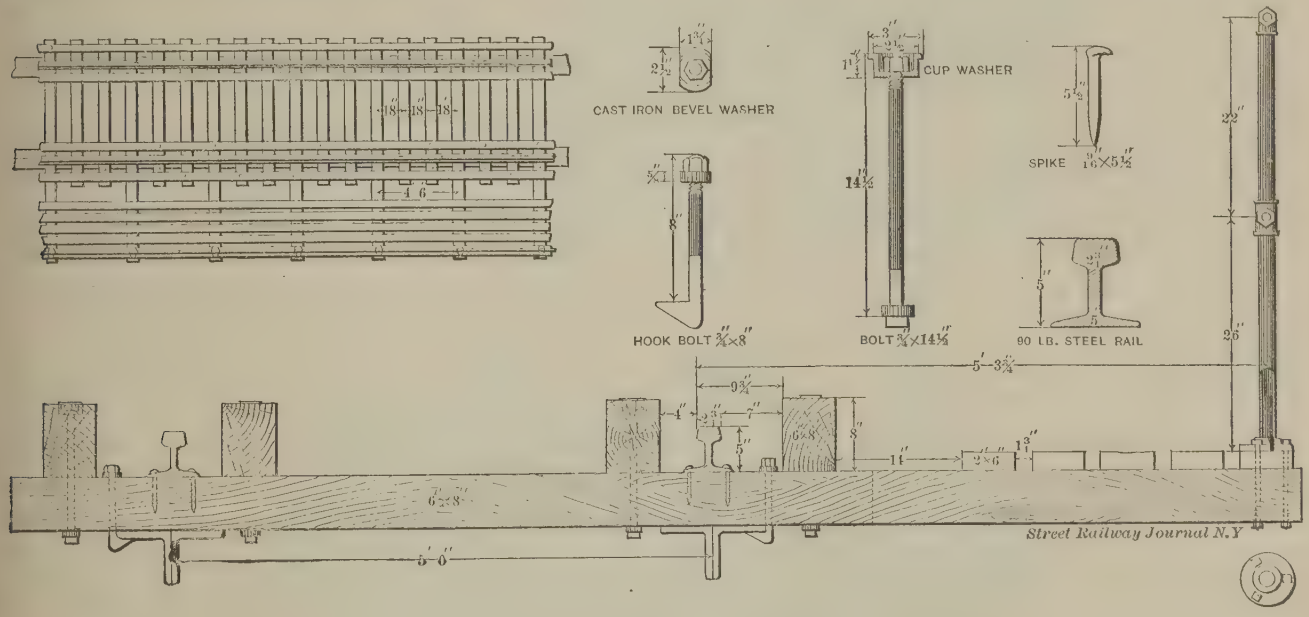


FIG. 387.—TRACK CONSTRUCTION.

low pine timber, except on curves, crossings and turnouts, where white oak blocks, cap stringers and shims are used; steel T rails weighing from sixty to ninety pounds per yard; fish plates, screw bolts, lag screws, clips, angle bar and strap iron guard, blunt bolts, spikes and nails.

In the earlier construction to which the last clause refers, the heads and washers of the guard rail bolts were countersunk, and the augur hole cups were filled, a little crowning, with cement paste, to shed water.

Owing to the difficulty of tightening up the bolts, it being necessary for the workmen to go beneath the track, and for other reasons, the method of construction, as shown in Fig. 387, has been adopted, and provides that all bolts may be tightened from the top, and prevents the possibility of nuts and bolts becoming loose and falling to the street. The guard timbers in the new construction, it will be noted, are placed farther from the rails than formerly, leaving room for the wheel between the rail and guard, and preventing its becoming wedged in case of derailment. The strap iron with which the guard timbers were formerly faced has also been omitted.

It is usual to lay every third cross tie on the main line twelve feet long, to provide a support for the plank side walk. This, in turn, is guarded with

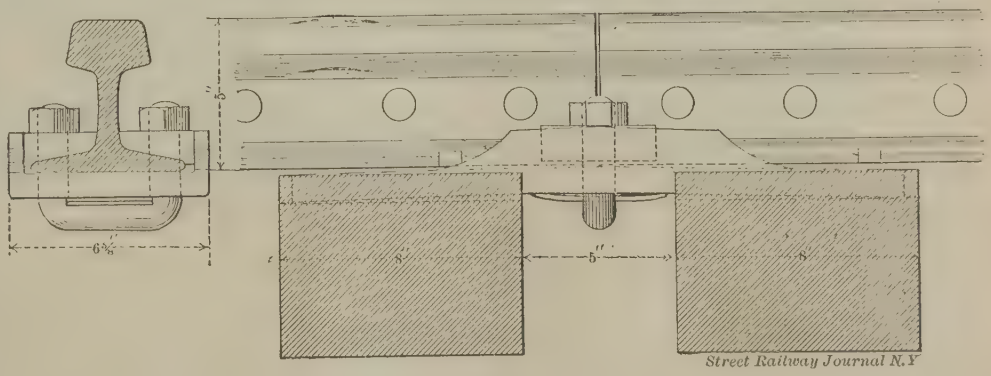


FIG. 388.—FISHER RAIL JOINT.

a hand rail, made of one and a quarter inch piping, as shown in the last figure.

In this connection it is interesting to note that a ninety pound rail is now employed on the New York lines, and the successive steps in the weight

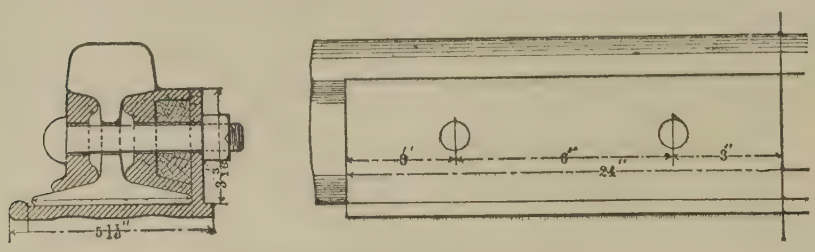


FIG. 389.—WEBER RAIL JOINT.

of rails employed, since the roads were built, have been as follows: Thirty-five, fifty, fifty-six, seventy and ninety pounds.

Fig. 388 illustrates the Fisher rail joint, quite extensively employed on the same lines, which gives fair results. The Weber joint, illustrated in Fig. 389 is also being tried. The Servis tie plate (Fig. 390) is an important appliance in elevated track construction, as it prevents the rails from cutting into the ties, and being provided with points which prevent its complete contact with the surface of the tie, it allows of a free circulation of air and prevents decay.

FIG. 390.—TIE PLATE.

The following is the amount of material required for the construction of 1,000 ft. of single track, old style: 250 cross ties, 6 ins. × 6 ins. × 12 ft.; 500 cross ties, 6 ins. × 6 ins. × 8 ft.; 3,000 wrought iron clips, 5½ ins. × 2½ ins. × ½ in.; 1,500 lag screws, 6 ins. × ¾ in.; 67 steel rails, 30 ft. long; 67 fish plates, 20 ins. × 2½ ins. × ¾ in.; 268 fish plate bolts, 4 ins. × ¾ in. with nuts and washers; 3,000 spikes, 7,000 lineal feet guard timber, 6 ins. × 8 ins.; 1,500 guard rail bolts, nuts and washers, 14½ ins. × ¾ in.; 150 lag screws, 12 ins. × ¾ in.; 2,000 lineal feet strap iron, 2½ ins. × ½ in. section; 300 strap iron bolts, 6½ ins. × ½ in. with nuts and washers; 300 blunt bolts for strap iron, 5 ins. × ½ in.; ¾ barrel Portland cement. The actual cost of laying 1,000 lineal feet of straight single track will be about $300.

A general plan for curve construction is illustrated by Fig. 391. The outer rail is elevated about three inches, this elevation being gained in a distance of about eighty feet on the tangent to the curve.

The guard rail and method of bracing the guard timbers are clearly shown in the illustration.

It is of the first importance that all surfaces of an elevated structure should be painted, and only the best material should be used. A metallic paint is recommended for the first coat and a white lead paint for the second. The following is a good formula for a metallic paint: Nine parts of boiled linseed oil, one part of turpentine, seven and a half pounds of ground iron ore, make one gallon of mixed paint, and sufficient to cover 256 sq. ft.

White lead paint, olive color, in parts sufficient to make 751 lbs. of mixed paint, that will cover 512 sq. ft., is compounded as follows: 325 lbs. white lead, 175 lbs. white lime, 75 lbs. French ochre, 3 lbs. Prussian blue, 1 lb. burnt amber, 21 gals. boiled linseed oil, 1½ gals. turpentine, 1 gal. liquid driers.

The iron work should first be thoroughly cleaned, rough spots scraped, and those with new rivets and other raw details covered with one coat of metallic paint. All seams and cracks should first be filled with linseed oil putty. All cracks, joints, sun checks in the timber, should be filled with

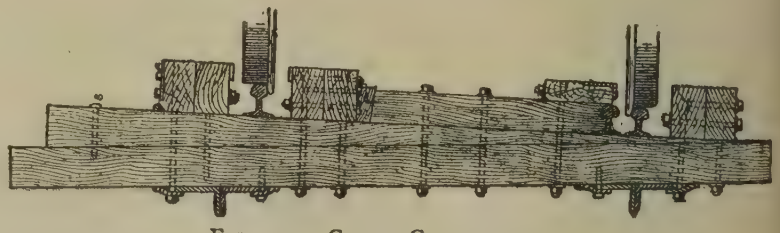


FIG. 391.—CURVE CONSTRUCTION.

putty, prior to painting with metallic paint, and again before applying the white lead paint. There should be two coats of metallic paint and a final coat of white lead paint, which should be laid on with great care.

The rolling stock suitable for an elevated road depends upon the amount of traffic and the grades. Most elevated roads are operated by steam locomotives. A few have cable power. Doubtless the time will come when all elevated lines will be operated by cable or electric power.

FIG. 392.—STANDARD LOCOMOTIVE—MANHATTAN ELEVATED, NEW YORK.

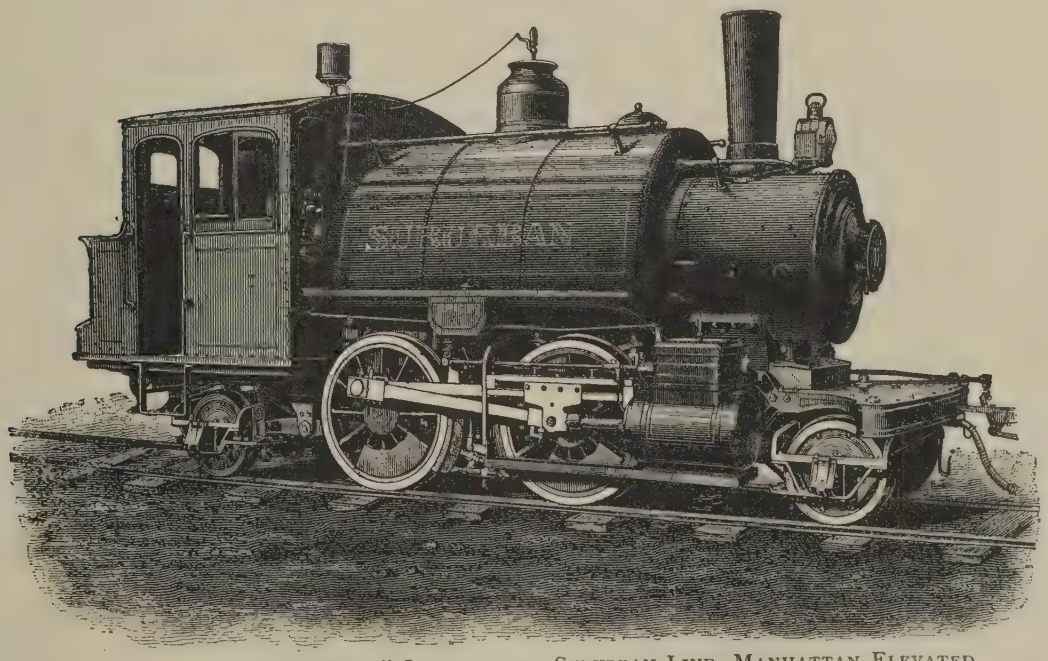


FIG. 392A.—"DOUBLE ENDER" LOCOMOTIVE—SUBURBAN LINE, MANHATTAN ELEVATED.

ENGINES.

The Forney type of locomotive engine with some modification, has been generally adopted for elevated railroad service (Fig. 392). As originally designed for the Manhattan lines, they were "double enders," but it was found that they operated better with only one truck, so the forward truck was removed, and in the new designs only the rear truck has been retained, and it is found that they operate even better with the drivers ahead; that is, when derailments occur it is usually when the truck is running ahead. With the drivers ahead the flanges are cut somewhat faster, but this is not a serious defect. "Double enders," however, are employed on the suburban line (Fig. 392). These have a pony truck at each end fitted with swinging bolster and

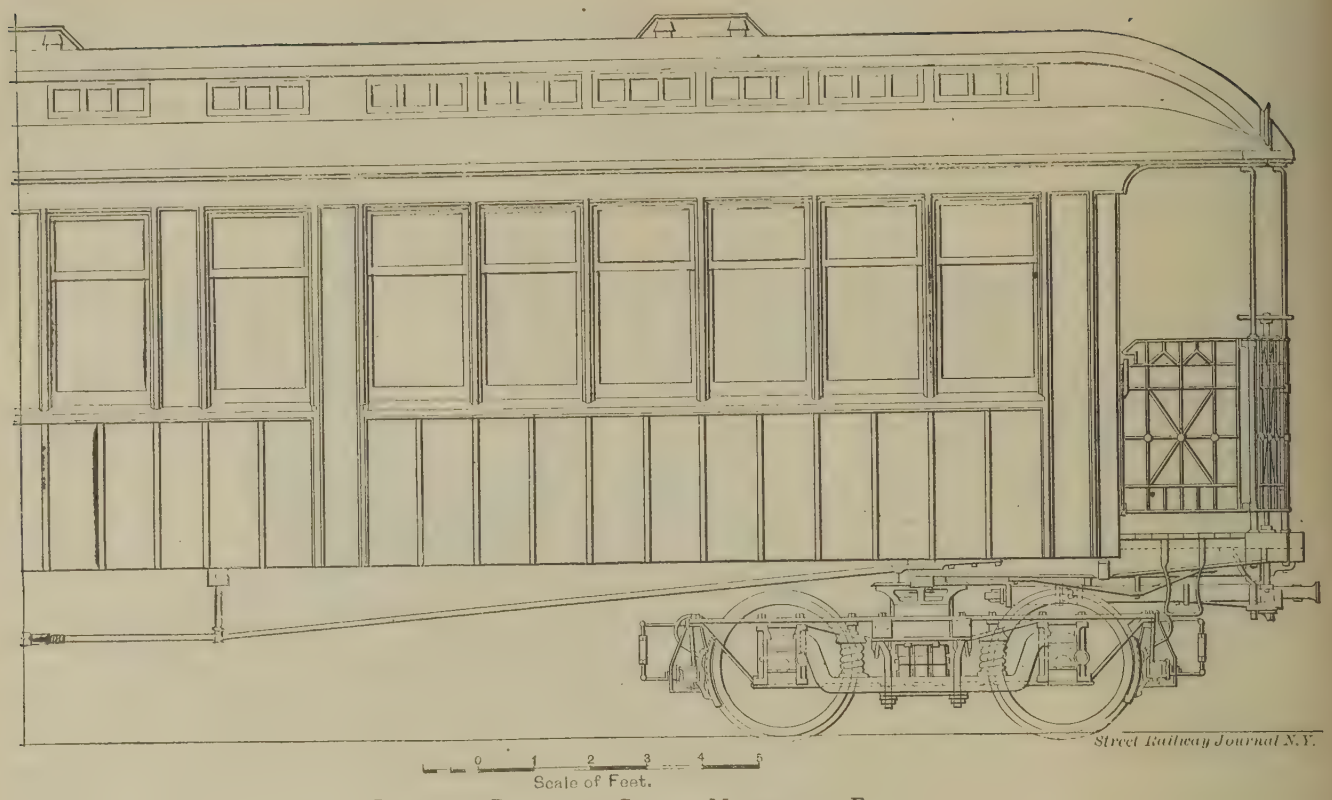


FIG. 395.—PASSENGER COACH—MANHATTAN ELEVATED.

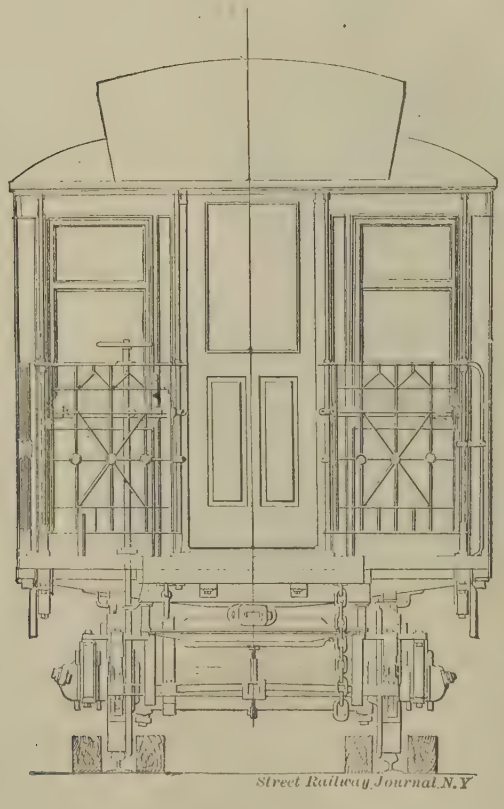


FIG. 393.

radial bar so that they curve easily, and do not cut the driver flange. The saddle tank, however, obstructs the view of the engineer somewhat, and makes the machine top heavy. This can be obviated by placing the tank and fuel box over one of the trucks. These two types of locomotive will meet nearly all the conditions of elevated service.

The general dimensions of the locomotive "Suburban," illustrated by Fig. 392A, which was manufactured by the Baldwin Locomotive Works, of Philadelphia, are as follows: Cylinders, 14 × 18 ins.; drivers, forty-eight inches in diameter outside tire; wheel base, five and a half feet; boiler, forty-four inches in diameter and six feet ten and a quarter inches long, with 160 one and a half inch tubes. Fire box, 51 × 45 ins., nearly. Tank capacity, 600 gals. Weight, including fuel and water, 60,000 lbs., with about 40,000 lbs. on drivers. These engines are designed to burn anthracite coal.

CARS.

The car bodies are usually of the same general type as for steam traffic, from forty-five to fifty feet over all, with double trucks (Figs. 393 to Fig. 399 in which details of framing are clearly shown.)

The drawbar should have sufficient swing to give clearance on short curves, and both continuous and

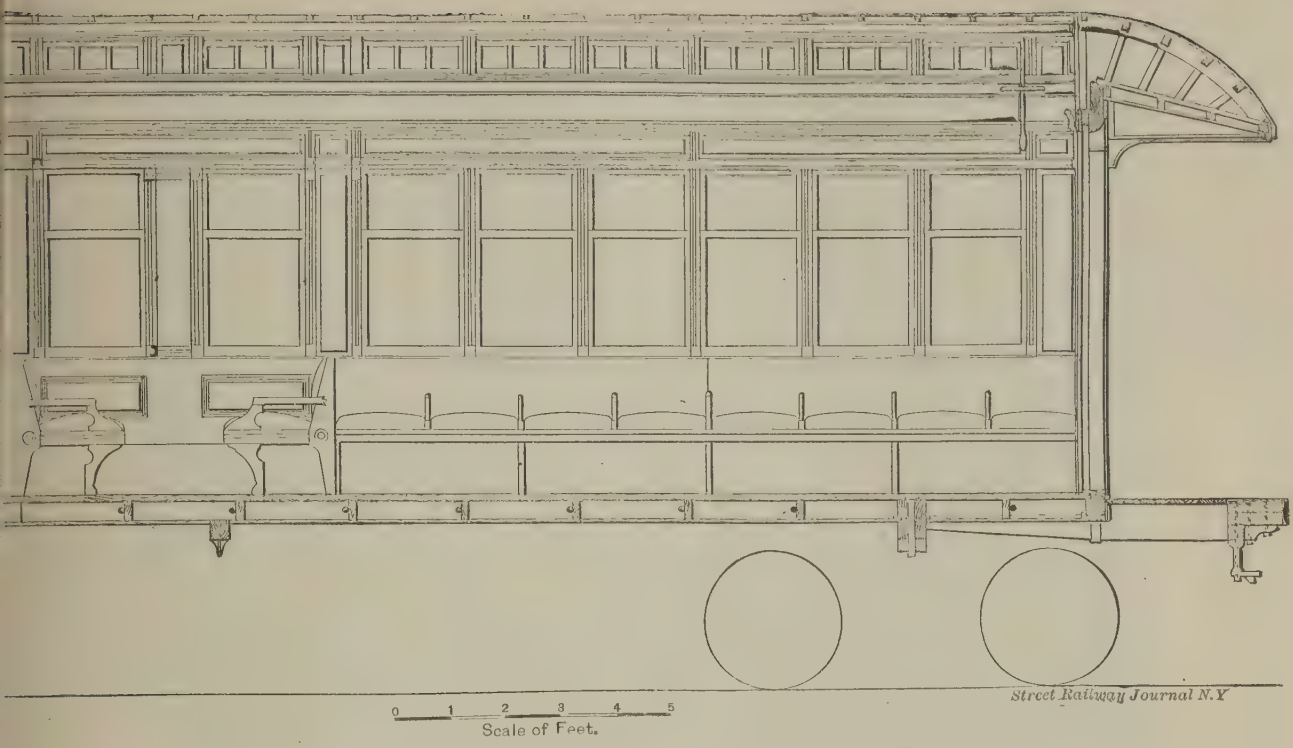


FIG. 396.—SIDE SECTION, PASSENGER COACH—MANHATTAN ELEVATED.

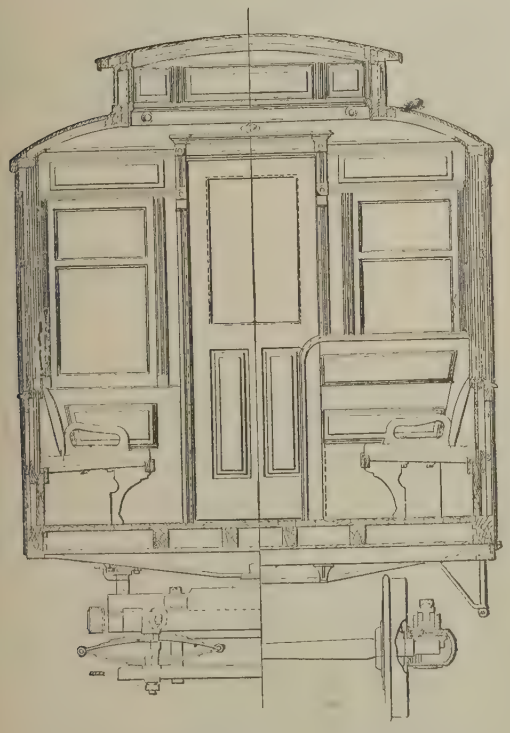


FIG. 394.—CROSS SECTION—ELEVATED CAR.

hand brakes should be provided. Iron gates and flexible guard gates are also necessary.

The seats may be arranged along the sides of the car, or both side and cross seats may be provided, as shown in Figs. 396 and 400. The cars should also be equipped with some of the well known systems of steam heating, and provided with fixtures for lighting, either by gas, electricity or oil.

COST.

The cost of an elevated line will depend largely upon the type and weight of girder adopted, the height of the columns, price of the material and the character of the soil on which the substructure rests. The approximate cost of one mile of double straight track, including station for each track, without any special construction, of the type of construction employed on Second Avenue, New York, (Fig. 358) may be stated as $600,000 ; that on Third Avenue (Fig. 360) as $500,000 ; Sixth Avenue (Fig. 365) $600,000.

The type of construction employed on the elevated lines of Brooklyn, N. Y. (Figs. 370 and 371), cost from $500,000 to $600,000 per mile, double track. The elevated line which has been in operation at Kansas City, Kan., for the past five years (Fig. 379), cost about $166,000 per mile without track rails, estimated as follows: Cost per pound, erected, five cents ; weight per lineal foot 478 lbs.;

foundations, $6.00 per foot of structure; stations $4,000 each.

The engines operated on this line weigh about 34,000 lbs. As an aid in planning the members of an elevated structure, engineers would do well t consult a work recently issued by the Railroa Commissioners of the State of New York, entitle "Report on Bridge Strains."

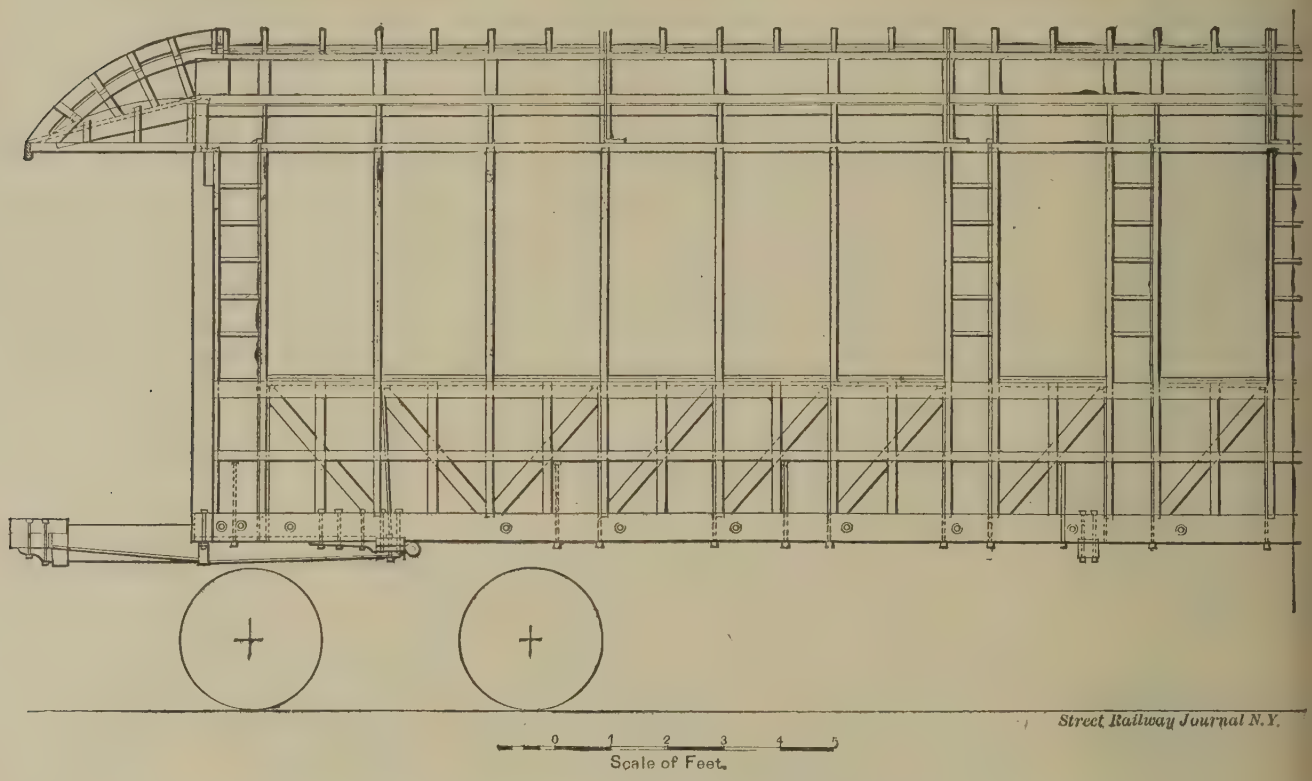


FIG. 397.—FRAMING OF ELEVATED PASSENGER COACH.

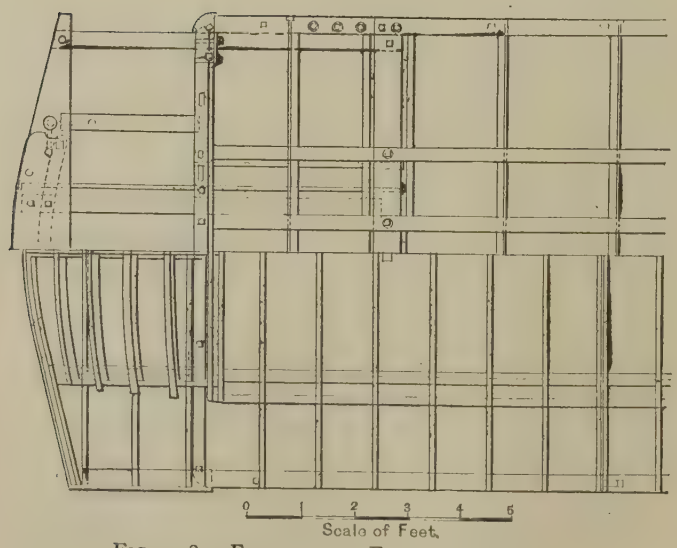


FIG. 398.—FRAMING OF FLOOR AND ROOF.

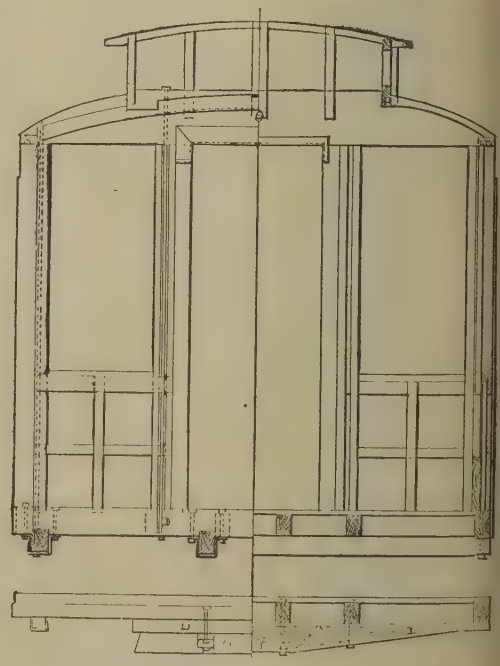
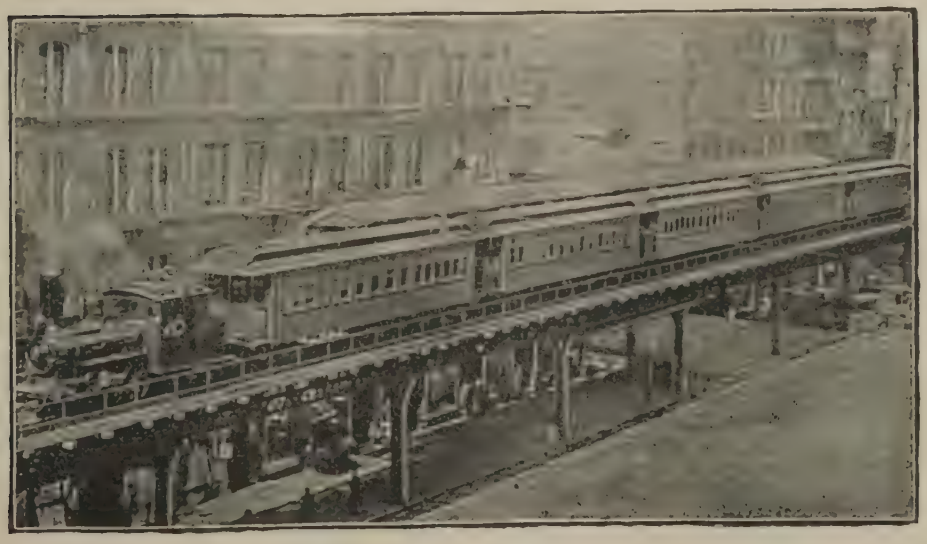


FIG. 399.—SECTION OF END FRAME.

FIG. 400.—INTERIOR OF ELEVATED CAR—MANHATTAN RAILWAY.



CHAPTER VIII.

CAR BUILDING.

The present American styles of street cars are a natural and legitimate product of American ideas. They differ greatly from the passenger vehicles of the first street railroads, for these retained to some extent the form and arrangements as well as the name of the omnibuses and stage coaches which they superseded ; and, naturally, for the mechanics of that day were only familiar with the construction of coach bodies. For instance : The form of the lower portion of the sides was made concave, a form necessary with an omnibus in order to provide space for its large wheels ; but with the street cars having small wheels, which are placed wholly under the body, the concave form is found to be unnecessary, and the tendency now is to build with sides vertical or nearly so, the concave form of the lower panel being retained in some cases for the sake of strength and appearance, and because it allows of passing street vehicles more readily where those stand in close proximity to the track, for the hubs of the latter, in case they extend slightly beyond the plane of the vertical sides, do not interfere with the concave panel.

Notwithstanding the many changes in the styles of cars which have been brought about during the past few years by the change in motive power, the ideal car that will meet all the conditions of rapid transit under any one kind of motive power is not to be expected, for different lines need different equipments. For instance: The style of car best adapted for use on narrow streets, with large traffic, where passengers are continually getting on and off the cars, from one end of the line to the other, would in some points be unfitted for the business of a line in a city having a large suburban travel, where the passengers are mostly taken on and let off near the termini. Hence it is that vestibule and long cars, and those of the Accelerator type are in favor in some localities, while for other localitie they are not so suitable. The time will come doubtless, when the type of car best suited to th requirements of certain conditions of traffic can b named. This desirable result can be reached onl after a large number of street railway companies i widely separated localities shall have each expresse an opinion as to what style or type of car would b best suited for their respective needs, when the ca builders can put the suggestions into practical form

Thus, it is apparent at the outset that an attemp to describe in detail the different styles of stree cars now in use, with particulars of constructio and material, would swell this chapter into a vo ume, or even many volumes. This is not desirabl but in order to supply a long felt want we shall at tempt to give an outline of street car constructio noting here and there the essential points that mus be observed in the making of any style of car, tha the product may have the combined attributes o beauty, lightness and strength. Let it not be ex pected that this chapter will prove instructive i all particulars to those who have long been engage in street car building, either for the trade or fo home use. It is not a treatise on the method which will be employed in works devoted to stree car building in the next century, but the practic of the present day, so that all the particulars mus necessarily be familiar to some one somewhere.

Different car works have each some special cha acteristics; not that they are larger, and differ i form, color or situation ; but, in the adaptation o means to ends, in the utilizing of labor saving ap pliances in the styles of cars turned out, there ar differences, and no one shop is so perfect that i cannot be made better by adopting some of th characteristics that are to be found in each of th others.

FORM A.

DETAILS OF ORDER No. 3900 - 20 cars similar to (3398) Spokane cars

For Denver Tramway Co — 6 cars
No. of Cars Kuhn Cos Date of Order, Dec 7 1891 Date of delivery at works, 14 " Jan 13 / Feb 9 } 1892
Dimensions Length over End Panels, 29 ft. Width at Belt Rails, 7 5 1/2"
Width over Sills, 6'9" Height, Height of bottom of Sills to top of top rail,
Bottom Frame Material and dimensions of Sills, 4 3/4 x 5 3/4" Thickness and material of Flooring, 7/8" yellow Pine.
End Sills, 5 3/4 x 9 1/2" Crossings, 3 1/2 x 5 1/2"
Posts Corner Posts, size and style, 3 1/4 x 4 1/4" sweep Side Post, size, 2 1/4 x 4 1/2 Door Post, size,
Top Rail, size, 1 3/4 x 3" Belt Rails, size, 3/16 thick Ventilator Rails, size, 1 3/4 x 3 1/8"
Curtains, Yes size, Lamberquins, None
Roof Monitor Deck Canvas or Boards, No. of Deck Sash on sides, 12 Transoms, Each end of roof
Cov with 10 oz duck
Windows No. on Sides, 4 Quality of Glass, American Plate Material of Blinds, No Blinds
Sash, High arched Painted outside or Varnished, Both.
Running Gear Pedestals, Boxes, Springs,
Wheels Diameter, 30" Tread, 2 1/2" Flange, 3/4" Weight,
Maker, Gauge of Track, 3'6" Kind of Rail,
Axles Material, Sketch, 3900 1/2 - 40 No 11 truck
Brakes Outside, Centre, Length of Axle 5'11 7/8"
Iron Work Steel Iron Rafters 3 in closed & one in each open Size, See D W Olds letter of 1/28/91 regarding mat Curves 35' Radius —
Brake bearers materials, wrt iron part Size,
Brake lever styles, Brake handles, kind and finish, 2202 mal bronzed
Brake shafts, where placed, one each end Combination face,
Brake shoes, kind, Latest Iron or Cast Rear, same dimensions, Same
Platforms Front D Jack Same Length from Iron over crown piece, 2'10"
Grab Handles and Window Rods Nickle plated, No Bronzed, Bronze. Painted, No.
Steps, on sides Length between step irons, Kind of tread, Wood
Dashers Height, 28" No. of iron, 16 Rails, nickled, blackened, or bronzed, Bronze. Wood strips, of ash or oak
Draught Pull irons, kind, Radiating draw bars Centre, 16" Pole No
Double and single trees, No from rail Pole or bar supports, No.
"Tow" eyes, No. Rafters No show in open comptS Poplars So. 1 boards

Inside finish of solid cherry Style finish, No 2 pat. Ceilings, 3 ply quarter oak veneer, duck ceiling only to be divided into panels for advertising racks — to receive cards 11" wide.
Side ceilings provided with moldings for
Over windows, Beaded mouldings —
End linings, Cherry
Doors Thickness, 1/8" Panels, Cherry — Where hung, on top —
Kind of sheaves and tracks, See cards. Bronze —
Kind and material of handles,
Kind of door, Sliding — Drop sash in door, No
Change slides, kind, none — One door or two, 2 -
Width, 2'1 1/2" opening — Materials, Cherry —
Seats and Backs How upholstered, Closed comptS cherry cov with Panasodie Milton carpet.
Quality plush, Open comptS Cherry & ash Quality hair, none
Spring seats, Slats - backs reversible. Lockers, Each end
Seats open beneath, closed Seats closed beneath, style and material of panels, closed
Mouldings Materials, cherry
Glass Quality, Best Lamex Plate Deck light, kind, Nine color embossed, Pattern,
Deck light lettering, none Deck sash, how hung, Pivotted.
Transom lights, pattern, Nine color embossed
Transom lights, lettering, none
Fare Box or Register Whose make, none Stove, None
Lamps Material of lamp box, none Kind of lamps, none
Kind of reflectors, None Kind and color of signals, none
Centre lamps, how many, none Whose make, None
Bells Number, two Where placed, one each end. Double or single hammer, single —
Bell cords, where placed, raw hide cord furnished, not put on.
Hand Poles Material, Cherry stained — Finish,
Brackets Material, Bronze trimmings inside — Shape,
Straps Material, No.
Sash and Blinds Materials, No Blinds — Pattern,
Lifts Lining sash, at each end of closed compt. Hinged sash, Yes Gauged sash, No.
Floor Mats Cocos, No. Cocos fancy, No. Plain wood, None Diamond wood, No. We do not furnish mats but for of closed compts arranged for mats 3' wide
Roof Signs Style and number, none
Inside Finish Gloss finish, Dull finish,
Painting Top panels, color,
Top panels lettering with material and shading,
Centre panel color,
Centre panel lettering,
Concave color, as desired
Concave lettering,
End lettering,
Dashers, coloring and lettering,
Running gears, color and striping
Numbers,

Space between centres, see Blue print Kind of seats, see above
Kind of panels, Rig outside Material of backs, Bronze —
Width of backs, Ash Material and pattern seat arms,
Material and pattern levers, 1105 mal Spanish Bronze,
Curtains, For Closed CompTs - Spring rollers of pattern & selected, Brown Jupe 7/8" in diameter to be place in lower edge of curtain with brass knob fitting in Jupe loosely to work in grooves —

No lamps furnished for ceiling of closed compts arranged for Edison
No oil combination oil or elec lamp.

Left guards of iron of cow catcher form.

Curtains — Jupe in open compts of selected duck with wide hem top & bottom & two additional rods equally spaced between with Brass knobs Curtains to run down to sill

Seats over motors to be 3 ft wide

Screens along sides between trucks same as on the Spokane cars - (3398)

Edison No 14 Single Reduction Motors.

Trolley bridge of oak 14" wide, raised from roof 1 1/2"

Pedal gong on each platform.

Seats over armature arranged with 98 section for removal of necessary.

Arrangements for taking out armature to conform to sketch as per D W Olds letter of 1/6/92

Mat locks to be used wherever possible.

Ante rattles of Bronze.

Seat risers to be set in about 6" and to have a door at each end about 2" x 6" opening downward with brass hinges & catch.

Materials to be inspected & passed upon by an inspector furnished by Denver Tramway Co

Mirrors as per pattern of best bevelled plate.

Space over door to be panelled as per sketch sent.

Two of our own make sand boxes

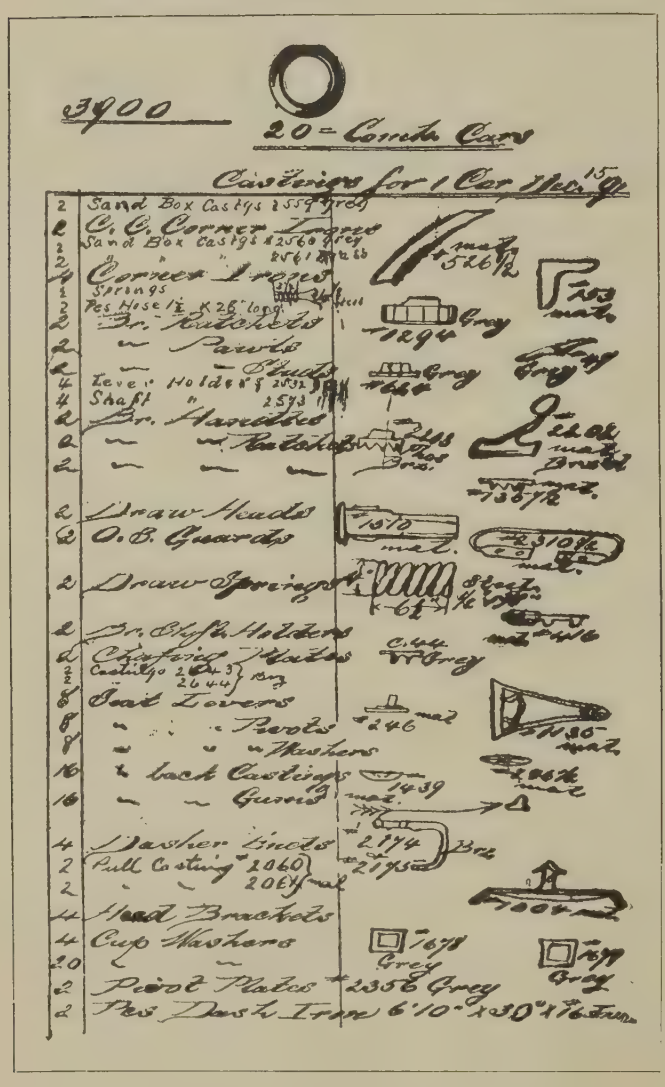
Drop over motor 2'4" wide x 3 ft long to permit of armature being easily removed. Strong bronze for raising provided & to be flush with top of floor.

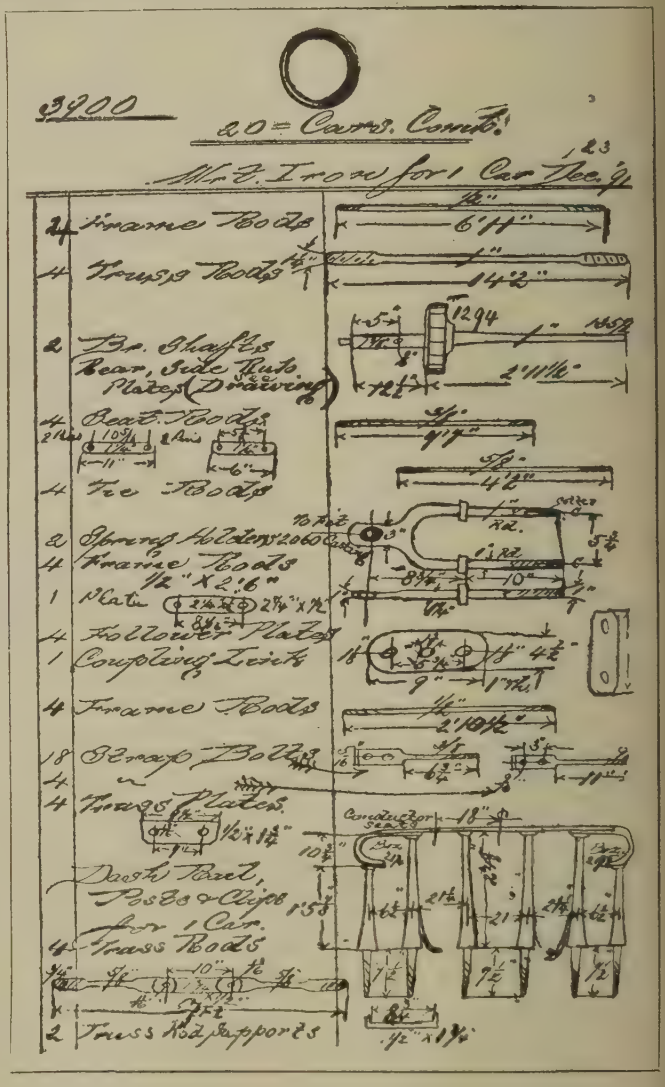
Awning boards of oak or ash with suitable cast iron brackets in place of rod as shown in sketch last and nearest closed pass

Stock for panels must be thoroughly seasoned one acct of such a dry climate as Colorado

There is a science in car building, but it has not yet become an exact science, and no one can study the designs of cars and methods of construction now in vogue and not be convinced that the business is still in its infancy, that the room for improvement is larger than the improvements already made, so that innumerable, marvellous and fruitful

FORM B. FAC SIMILE OF SHOP CARDS.—ONE-THIRD SIZE. FORM C.





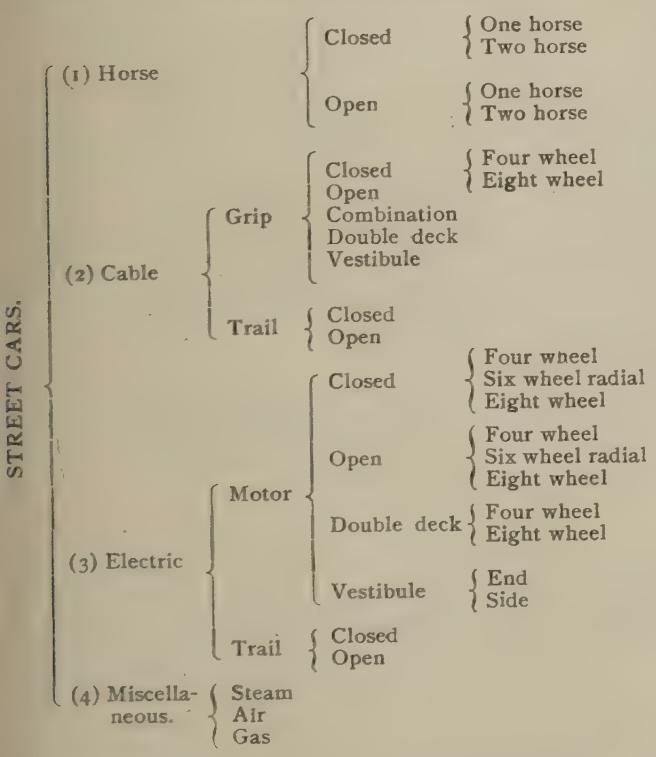
discoveries await the future workers in the line of street car building.

The increased patronage awarded to steam "palace cars" and lavishly furnished great hotels, strikingly illustrates the curious tendency of modern travellers to demand luxuries and showy trappings in public conveyances and hostelries greatly beyond what most of them enjoy or would enjoy in their own homes. This tendency is spreading to the street car, and as the character of the cars is improved, so much more will people ride. The love of ornament is inherent in human nature, and for this reason those who provide means for comfort should at the same time administer to their love of beauty. But in the combination of the æsthetic with the useful, good judgment and care must be exercised. Carvings and upholstery that are easily broken or soiled, or that will accumulate dust and soon look dowdy, should be avoided. Elements of beauty, however, may enter largely into ceiling and deck light finish, and since the art of manufacturing the materials for this purpose (three ply veneer and ornamental glass) has reached so high a state,

his line of decoration is plentifully and cheaply upplied. Not only should a reasonable amount of lecoration be provided in cars which are patronzed wholly by a cultivated class of people, but in ll cars, for by this means the comforts and solaces f fine art will be brought to a large number of ives and hearts that cannot afford to provide them n their own homes.

This chapter, it is believed, will prove helpful, in ome particulars, to the veterans in the business, o new men engaging in this line of work, and also erve as a medium by which men engaged in the peration of street car lines may communicate inelligently with commercial car builders, or with men employed in their own repair shops, while it gives to the general reader a "speaking acquaintance" with this particular industry.

In present practice we find four distinct types or kinds of street cars, each of which may be subdivided according to the following diagram:



It is important in order to secure a durable construction that the well defined laws of architecture —of which street car building is a branch—be not violated. For instance: The walls of a brick building are not safe until the roof is put on, and yet, if the walls be not of sufficient strength, the roof will crush them or cause them to bulge, thus rendering the building unsafe. The same is true in car building; the construction of the body to the top plate must be properly done, and supplemented by a roof properly put on. The frame and panels also bear a mutual relation to each other. It is practically impossible to fit and set up the framework of a car so that it cannot be easily thrown out of position, causing a movement in every joint, but when the panels are properly put on, combining the different parts, the body becomes stiff, and capable of resisting severe shocks without injury. Some of the principles of construction may be noted as follows: Strong sills and bottom frame, proper mortising and tenoning of vertical framework, proper combination of panels and framework, a light roof (as light as possible), uniting the sides and ends, and these in turn carrying and supporting the roof.

As it requires over 1,300 separate pieces of wood to build an ordinary sixteen foot electric car, it is apparant that great care must be exercised in combining these parts, lest some defect enter into the construction, and prove a destructive factor after the car is put in service.

Hence, to properly construct the different kinds of cars it is necessary to consider the particular work they have to do, and where the principal strains will come, depending upon where the power is applied.

The horse cars and trail cars should be light, strong and durable, with as little heavy lumber as possible, unless a change of motive power is contemplated, when they may be built heavier and so framed as to be readily changed and adapted for mechanical power.

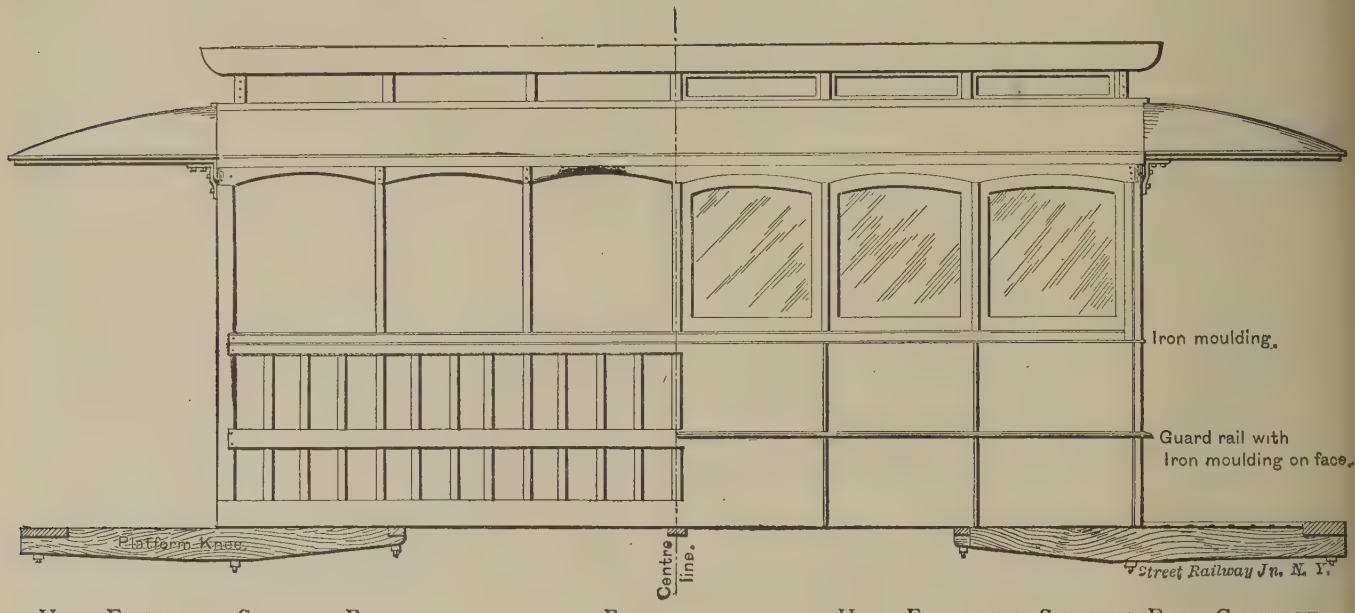
The cable car must have a strong under frame, put together with heavy timbers, and a neat and strong body, avoiding, as much as possible, a clumsy look.

The electric car must have a strong under frame, with cross timbers so arranged that portions of the floor may be removed to give access to the motors, and, if it is operated by the overhead system, the

roof should be specially strengthened to support the trolley stand and the weight of the workmen who are required to adjust or repair the same, while the extra weight at the top, increased speed and lurching, require that the framing throughout be stronger and heavier than on other types of cars.

INCEPTION.

The purchasing officers of street railway companies either furnish drawings and specifications of the cars they may desire to have built, or they merely state the dimensions and general style of the car they desire, after having examined the drawings or photographs of different styles of cars



HALF ELEVATION, SHOWING FRAMING. FIG. 401. HALF ELEVATION, SHOWING BODY COMPLETE.

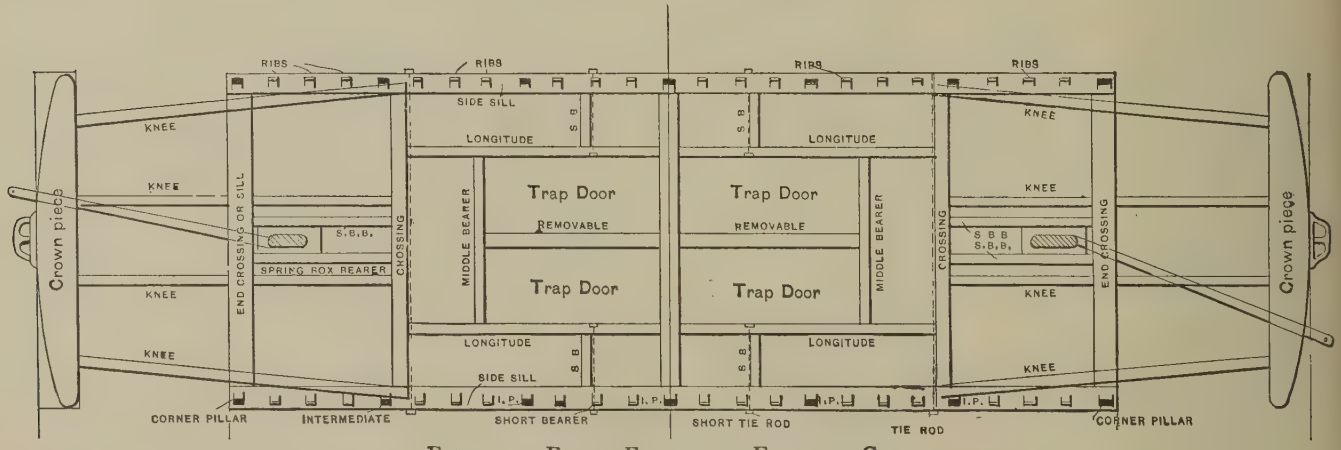


FIG. 402.—FLOOR FRAME FOR ELECTRIC CAR.

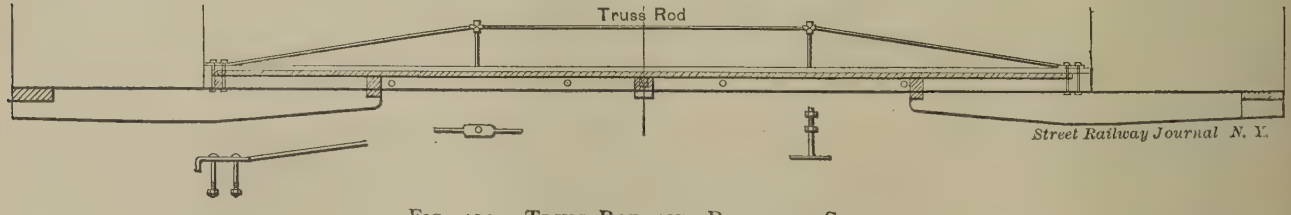


FIG. 403.—TRUSS ROD AND PLATFORM SILLS.

nat have been previously built, with which most hops are supplied, or after having visited the works f the manufacturer and studied the different types n process of construction, when the chief designer f the shops where the cars are to be built, after ull conference with the parties desiring to purchase, nakes detailed drawings and full specifications. After these have been approved and accepted, and he contract has been closed it is entered on the

In addition to the general drawings, it is the practice in some shops to provide details for the different departments. These may be gotten out in plain style with free hand sketches on sheets which are pasted to thick cardboard, and shellacked to prevent soiling (Forms B and C).

The general drawings usually show, first, an elevation of side and end of a car frame (Figs. 401 to 409), then, in detail, the sills and floor framing

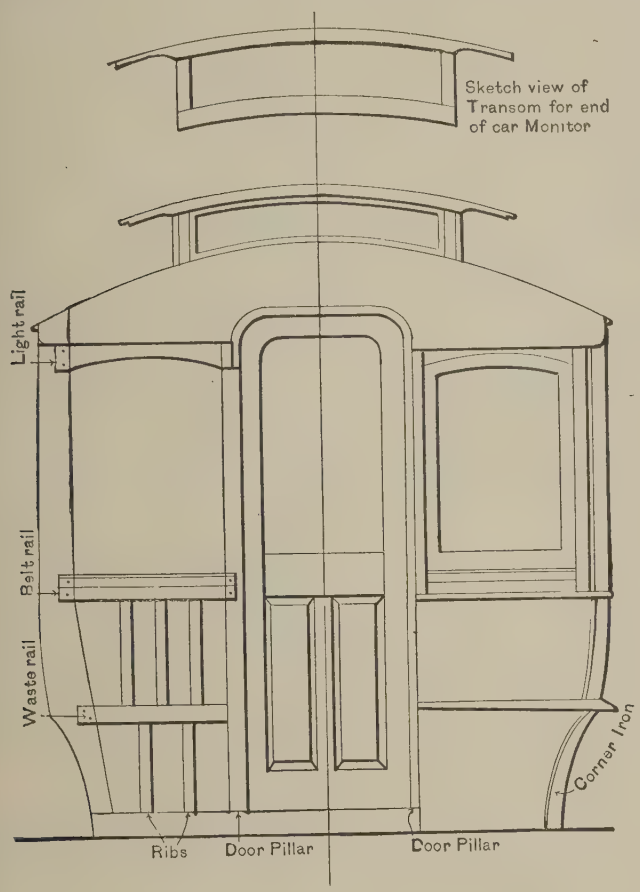


FIG. 404.—END ELEVATION, HALF IN FRAME.

FIG. 405.—SIDE POST.

FIG. 406.—CORNER POST.

order list which gives, first, the number of cars, name of company ordering, date received and date for delivery. This is filed in a large envelope into which all papers pertaining to the order are placed. A large detail book is also provided, which is printed with headings having blank spaces into which the general details are entered (Form A). The manager of the shops then receives written directions quoted from the specifications, with drawings which are numbered and known as shop orders for a particular lot of cars.

and all matters relating to the floor. The drawings of the side framing show the side posts and side bracing and side panels Another set of drawings exhibits the details for the deck, including everything above the side frame, such as carlines, deck posts, deck sills, deck plates, and side plates, beginning at the top of the posts. There are also drawings showing the ceiling finish or headlining. There are full detail drawings of hoods, platforms, carvings (Fig. 407B and C), and even of the bronze trimmings, however small. Some of these details rank as

"standard," and go into all kinds of street cars built at the shops.

The following are copies of actual shop orders, which will give some idea of the amount of detail incident to the business:

DESCRIPTION OF ONE CLOSED ELECTRIC STREET CAR.

Plan.....310-U. Length over sills, sixteen feet. Width over sills, five feet eleven and one quarter inches; over all, seven feet ten inches. Height over all ten feet four inches.
Roof.....Three (five) iron carlines, strengthened and arranged for trolley.
Hoods.....Removable.
Framing.....Closed street car. Height from top of sill to under plate five feet ten inches.
Outside.....Panelled with white wood.
Flooring.....Yellow pine.
Window sash.....Mahogany.
Blinds.....Mahogany frames and basswood slats.
Glass, windows.....Crystal sheet.
Glass, doors.....Crystal sheet.
Glass, decks.....Embossed.
Mirrors.....Plate glass bevelled.
Inside finish.....Mahogany.
Ceiling.....Burl oak, decorated with gold.
Lamps, centre.....Two, one (1) light.
Heater.....One coal stove placed in a zinc lined box.
Seats and backs.....Spring placed longitudinally.
Seat covering.....Wilton carpet.
Trimmings.....Bronze.
Bells.....One at each end with leather bell cords.
Gongs.....One under each platform.
Door catches.....Placed on each door.
Fare register.....One.
Lenses.....Red glass at each end in upper deck.
Change gates.....In each door.
Floor matting.....Standard diamond.
Body grab handles....Bronze.
Steps.....Steel steps, Stanwood pattern.
Platforms.....Standard, open at sides.
Dash boards.....Iron, closed centres.
Dash grab handles....Bronze.
Brake handles.....Bronze, adjustable.
Brakes.....Operated by hand on all wheels from platforms.
Track brake.....To be applied for use on grades and for sudden stoppages.
Sand boxes.....Four.
Platform gates.....Four folding, iron.
Life guards.....On each end of truck.
Track cleaners.....To be applied in front of each wheel.
Headlights.....One arranged for electricity.
Draw bars.....Standard radial.
Running gear.....Four wheel gear, as selected by purchaser.
Motors.....As selected by purchaser.
Gauge.....Four feet eight and one half inches.
Wheel base.....Six feet.
Wheels.....Cast iron, thirty inches in diameter, with two inch tread and five-eighths inch flange.
Axles.....Steel, three and one-half inches in diameter.
Painting.....May be what is known as "Standard Broadway," which is a cadmium yellow.
Decoration.....To correspond with body color.
Lettering.....LIDGERWOOD" on sign boards. "WASHINGTON" on main panels.
Number.....1
Electric light.....Car to be lighted by electricity.

SPECIFICATIONS OF A CLOSED, DOUBLE TRUCK ELECTRIC STREET CAR.

Plan.....831-B. Length, twenty-two feet ten and three quarters inches over body; twenty-nine feet two and one-half inches over car, and thirty feet five inches over all. Width, seven feet one and one-eighth inches over all.
Roof.....Strengthened with five iron carlines, and arranged for trolley.
Hood.....Detachable on rear end.
Framing.....With straight post. Height from top of sill to under plate, five feet eight and one-quarter inches; over all, eleven feet two inches.
Outside.....Sheathed with white wood.
Flooring.....Yellow pine.
Window sash.....Cherry.
Blinds.....Cherry frames and basswood slats.
Glass windows.....Double thick French.
Glass doors.....Double thick French.
Glass decks.....Ruby colored glass.
Mirrors.....Bevelled plate glass.
Inside finish.....Cherry.
Ceiling.....Maple.
Centre lamps.....Two two (2) light.
Seats and backs.....Ash and red birch slats, covered with Wilton carpet.
Trimmings.....Bronze.

Bells	One at each end.
Gongs	One under front platform.
Door locks	One on cab door.
Fare registers	One per car.
Floor matting	Applied.
Body grab handles	Bronze.
Steps	Stanwood steel, double tread.
Platforms	Arranged with cab on front end and rear end, open on one side only.
Dash boards	Iron, on rear end only.
Brakes	Hand brake on both trucks, operated from platform.
Brake handles	Cast iron brake wheel in cab and bronze brake handles on rear end.
Air brake	Sessions patent.
Sand boxes	Two per car.
Life guards	On front truck.
Headlights	One, arranged for oil.
Draw bars	Radial on rear end and buffer on front end.
Running gear	Four wheel double trucks.
Gauge	Five feet two and one-half inches.
Springs	Coil.
Wheel base	Four feet six inches.
Wheels	Thirty inch steel, two-inch tread.
Axles	Iron, three and three-eighths inches in diameter.
Motors	Two fifteen H. P.
Painting	Light yellow, with carmine panels.
Lettering	"CENTRE & NEGLEY AVENUES" on each side of car at centre.
Number	55.
Lamps	Two pilots and a three cluster electric.

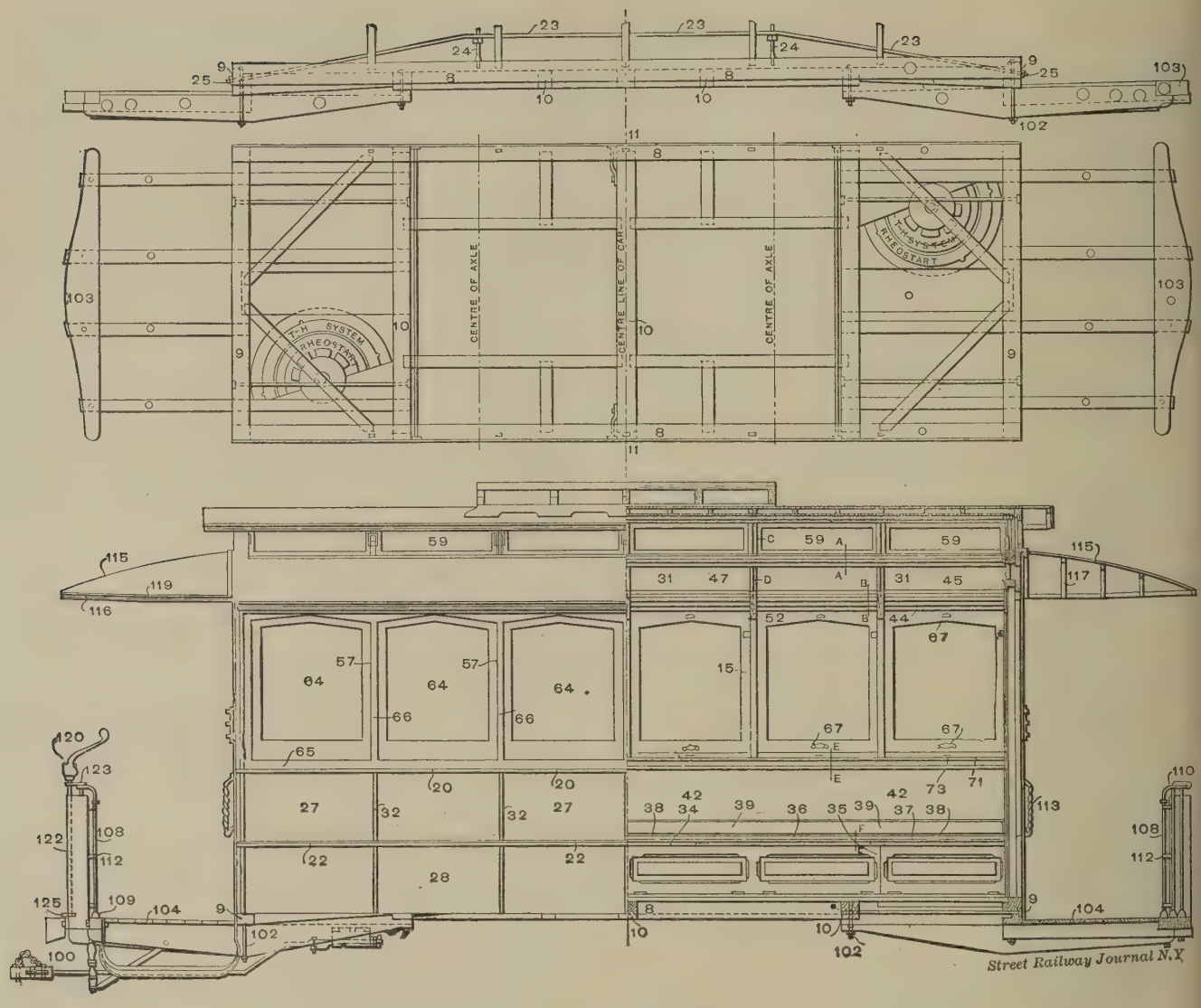
The above method of providing drawings and specifications is recommended for use in large shops, and in some modified form in all works, whether engaged in building for the trade or in constructing home-made cars, as it will be found to save time and insure the perfect fitting, when assembled, of such parts as are prepared by different gangs of workmen. It is the practice in some shops, however, to make all the detail drawings full size on large boards, which are placed in a convenient position so that the workmen have access to them, and from which they make their own measurements. The full sized drawings, it is claimed, insure a better fitting of parts. Figs. 407 to 429 illustrate the leading types of cars as made by different builders.

MATERIALS.

Storehouses and yards are provided for the different classes of material which is usually kept in stock, and includes lumber, glass, wrought, cast, malleable and sheet iron, steel, paint, varnish, cloths, plush and other upholstery goods, nails, tacks, screws, hinges, catches, locks, and other small hardware and metal goods (trimmings) that are too numerous to mention. Some large car building establishments manufacture their own veneers, trimmings and, in fact, everything entering into the construction, even the paints and varnish. Others purchase from manufacturers trimmings, etc., ready finished for their place in the car; while a few street railway companies, which build their own cars, purchase everything, even woodwork, in which case the work of the car shops consists merely in fitting the parts, painting, furnishing and decorating.

The number of tradesmen and mechanics who must have a hand in preparing material and finishing a street car is nearly a hundred. The list includes the following:

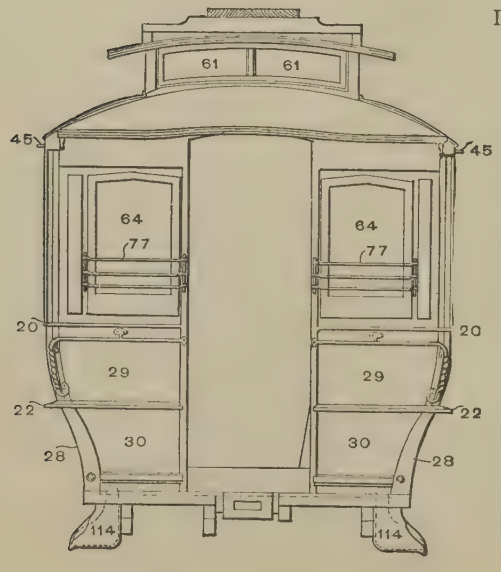
Car builder,
Sawyer,
Carpenter,
Joiner,
Cabinet maker,
Turner,
Veneerer,
Carver,
Machinist,
Blacksmith,
Iron founder,
Brass founder,
Engineer,
Spring maker,
Seat maker,
Pattern maker,
Upholsterer,
Hardware dealer,
Glue maker,
Varnish maker,
Paint maker,
Lamp maker,
Carpet weaver,
Steel master,
Stove maker,
Plumber,
Pipe fitter,
Wheel maker,
Glazier,
Glass blower,
Glass Etcher,
Gilder,
Painter,
Ornamental painter,
Tinsmith,
Electrician,
Electroplater,
Wire drawer,
Rubber manufacturer,
Engraver,
Chaser,
Mirror maker,
Fresco painter,
Letterer,
Axle maker,
Draughtsman,
Gold beater.
Plush maker,
Silk manufacturer,
Cotton manufacturer,
Linen manufacturer,
Woolen manufacturer,
Thread manufacturer,
Locksmith,
Mat maker,
Brush maker,
Tanner,
Rattan braider,
Turpentine distiller,
Oil cloth manufacturer,
Trimming manufacturer,
Burnisher,
Sewing machine manufacturer,
Sewing machine operator,
Bookkeeper.
Photographer.
Armature winder.



Scale of Feet.

0 1 2 3 4 5 6 7 8 9 10

FIG. 407.—SIXTEEN FOOT ELECTRIC CAR—LEWIS & FOWLER MANUFACTURING CO.



LIST OF CAR PARTS.

1. (Fig. 409.) Wheel.
2. Axle.
4. Journal box.
6. Side journal spring.
8. (Fig. 407.) Sill.
9. End Sill.
10. Transverse floor timbers.
11. Sill tie rod.
15. (Fig. 407A.) Window post.
17. Corner post.
18. Door post.
19. Belt rail.
20. Belt rail band.
21. Fender rail.
22. Fender guard.
23. Body truss rod.
24. Body queen post.
25. Truss rod plate
27. Outside panel.
28. Lower outside panel.
29. Upper end panel.
30. Lower end panel.
31. Inside frieze panel.
32. Panel strip.
33. Panel furring.
34. Seat bottom.
35. Seat leg.
36. Front seat rail.

38. Back seat bottom rail.
39. Back seat rail.
40. Lower seat back rail.
42. Seat back board.
43. End seat panel.
44. Upper belt rail.
45. Window ledge.
47. Plate.
48. Eaves moulding.
49. Window blind rest.
50. Window sash rest.
73. Window blind lift.
77. Window guards.
78. Door stile.
79. Door mullion.
81. Middle door rail.
82. Top door rail.
85. Mirror.
86. Door case sash.
89. Fare wicket.
91. Sliding door handle.
102. Platform timber clamp.
122. Brake shaft.
123. Upper brake shaft bearing.
125. Brake ratchet wheel.
125. Fig. 409.—Side hand rail.
151. Revolving seat back.
152. Seat spindles.
153. Bracket.
158. Seat rail.

LUMBER.

The enormous strains to which the frames and covering of street cars are subject, make it absolutely necessary that they should be made of the best lumber prepared in the best manner. Hence, to insure durability and long life, great care must be exercised in the selection and seasoning of the lumber.

In the selection of any particular wood its appearance should not always govern, but the region in which it grew should also be considered, for the locality has much to do with the texture of woods of the same name. In some cases, however, the supply has been exhausted in the regions which pro-

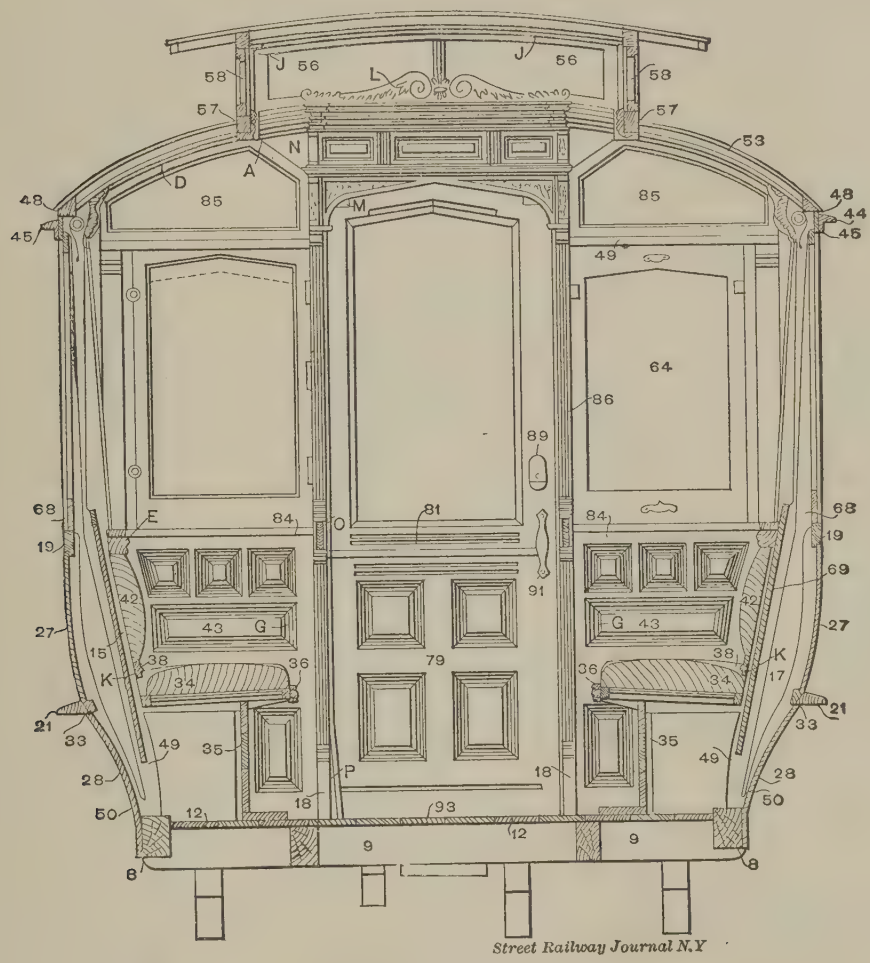


FIG. 407A.

51. Outside window stop.
52. Inside window stop.
53. Carline.
56. Upper deck.
57. Deck bottom rail.
58. Deck post.
59. Deck window.
61. Deck end ventilator.
64. Window.
66. Window stile.
67. Sash lift.
68. Sash stop bead.
69. Window blind.
72. Window blind mullion.
103. Platform end timber or crown piece.
108. Platform post.
109. Platform post boss washer.
110. Platform rail.
112. Dash guard straps.
113. Body hand rail.
114. Side step.
115. Hood.
116. Hood bow.
117. Hood carline.
119. Hood moulding.
120. Brake shaft crank.

duce the most desirable qualities, so that in this respect no choice is left, and a change of wood for the same purpose is sometimes rendered necessary.

The woods principally used in car building are of both native and foreign growth. The native woods include ash, white, Norway and yellow pine, hickory, basswood, poplar (whitewood), birch, butternut, cedar (both green and mined), cherry, cypress, gum, elm, white oak (second growth), burl oak, maple and sycamore. Of the foreign woods, mahogany, satin wood and teak constitute the principal kinds employed in this industry.

The seasoning process should occupy two years or more, and much of it requires to be kiln dried in drying kiln; for heavy sill timbers, from three to four months where the temperature, ranging from seventy-five to one hundred degrees, should be regulated to suit the conditions, care being taken not to destroy the life of the wood. In case, however, the structure is designed for service in high and dry latitudes, it is often necessary to continue the seasoning process till all moisture is expelled, or otherwise checks will appear and the car will soon go to pieces. After leaving the kilns, the material, if not at once needed, should be stored in closed sheds.

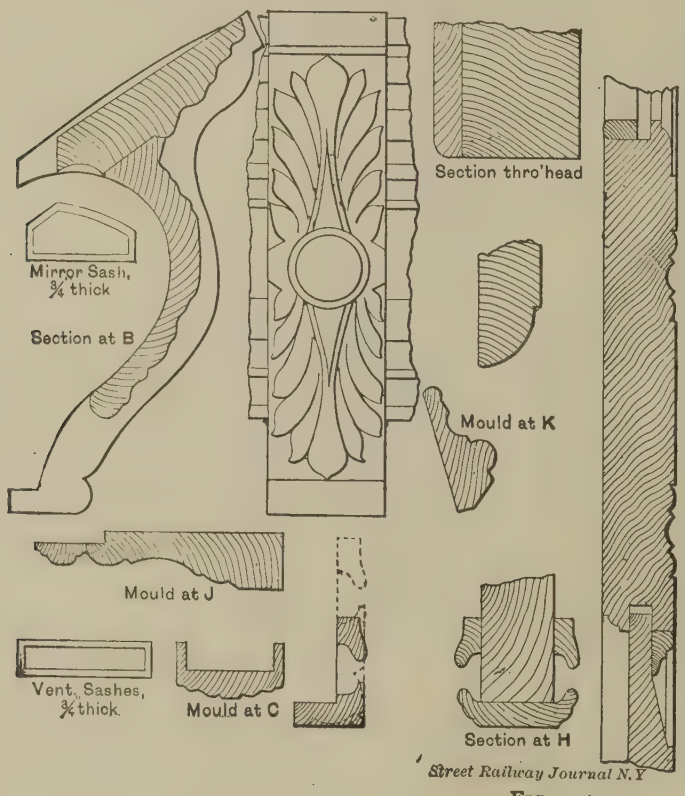
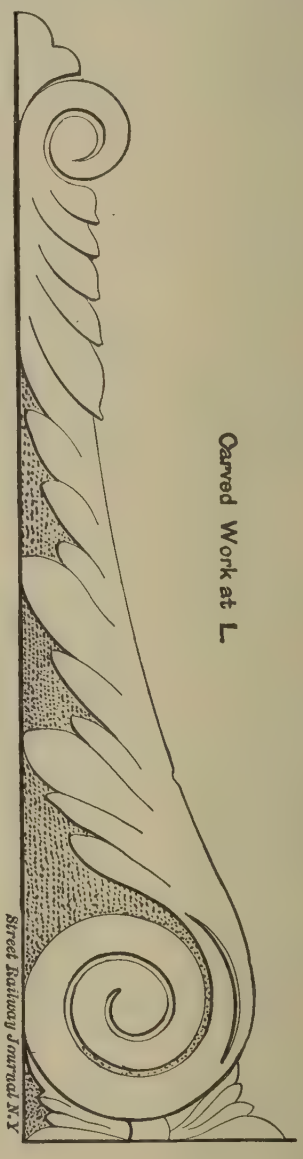


FIG. 407B.



addition. The lumber having been purchased, it is piled with the ends toward the prevailing winds in open order in the lumber yard, or, better, under sheds when these can be provided. It is also of advantage to cover the ends of all boards and sticks of timber, as soon as the lumber is piled, with some kind of heavy paint to prevent season checking.

The kind, size and condition of the stock determine the time the material should remain in the

In large establishments, the work of car building is usually subdivided, and several gangs of men do the work in successive stages; in some cases by

contract in others by day work. The lumber, when ready, is delivered to the wood working shop, usually on trucks, the yards and shops being provided with trucks for their accommodation. It is then cut into proper dimensions and passed to the planers, when the further work to be done upon material, and the nicety with which just the number of pieces of all kinds are made which are required for a given lot of cars, frequently covers the margin of profit in certain orders.

As the work progresses through the different departments it should be *carefully and continually in-*

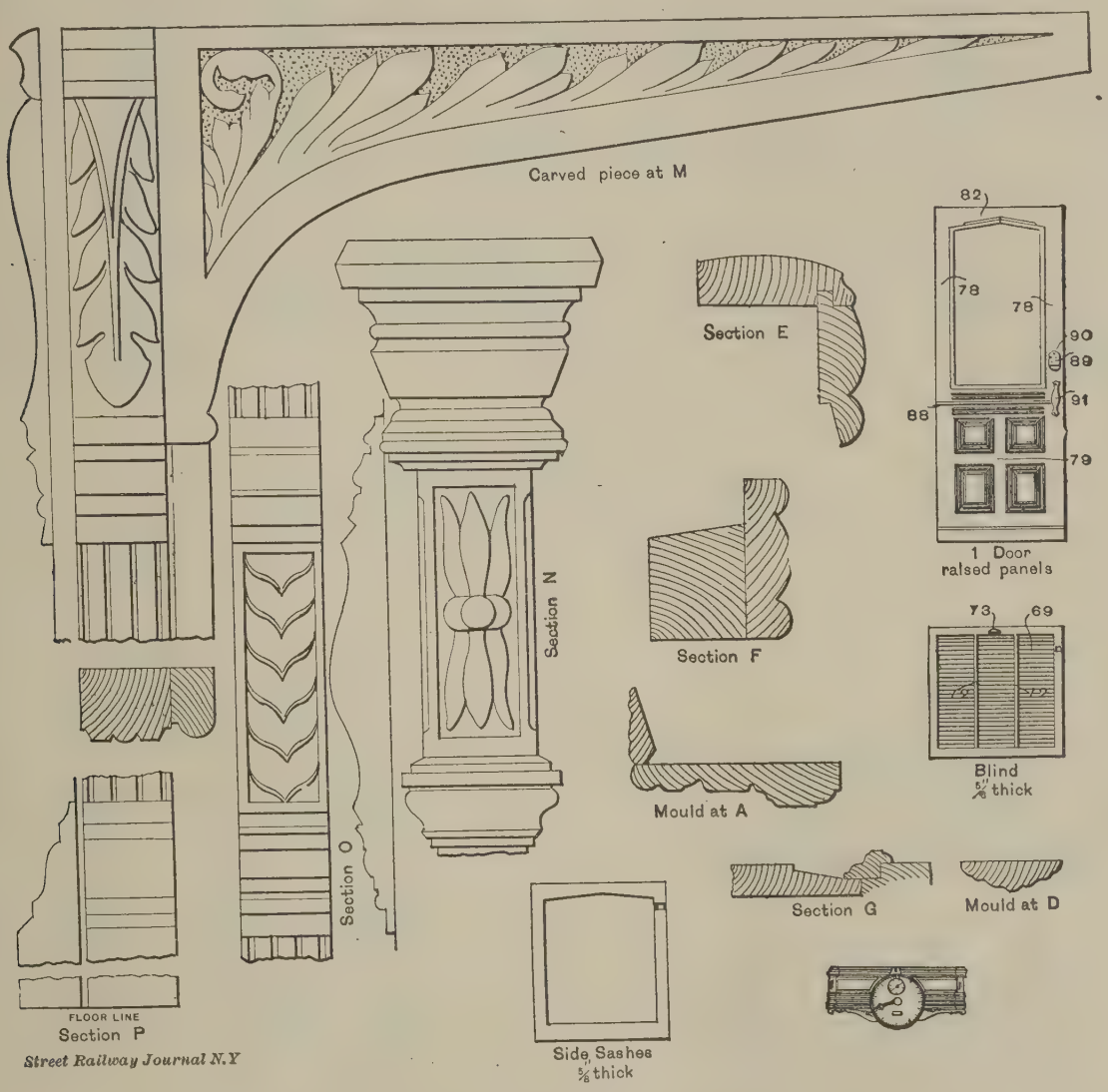


FIG. 407C.

it is laid out from templates by the foreman. It then goes to the shapers and mortising machines, and the small pieces are put through scrapers and sandpapering machines, and made ready for the blind builders and cabinet makers.

The economy exercised by the manager or shop foreman in laying out and utilizing all the building

spected by the manager or a special inspector, to see that the work of each gang is properly done. Even with the most careful supervision it will sometimes be found that the different cars for the same order, when finished, vary in real value a good many dollars, owing to the superior skill, or want of it, or honor on the part of the individuals composing

the different gangs of workmen, although the material for each was the same and prepared in the same manner.

the floor. In some cases this work is done by the same men that construct the body. If it is a sixteen foot electric car that is being built, we have two

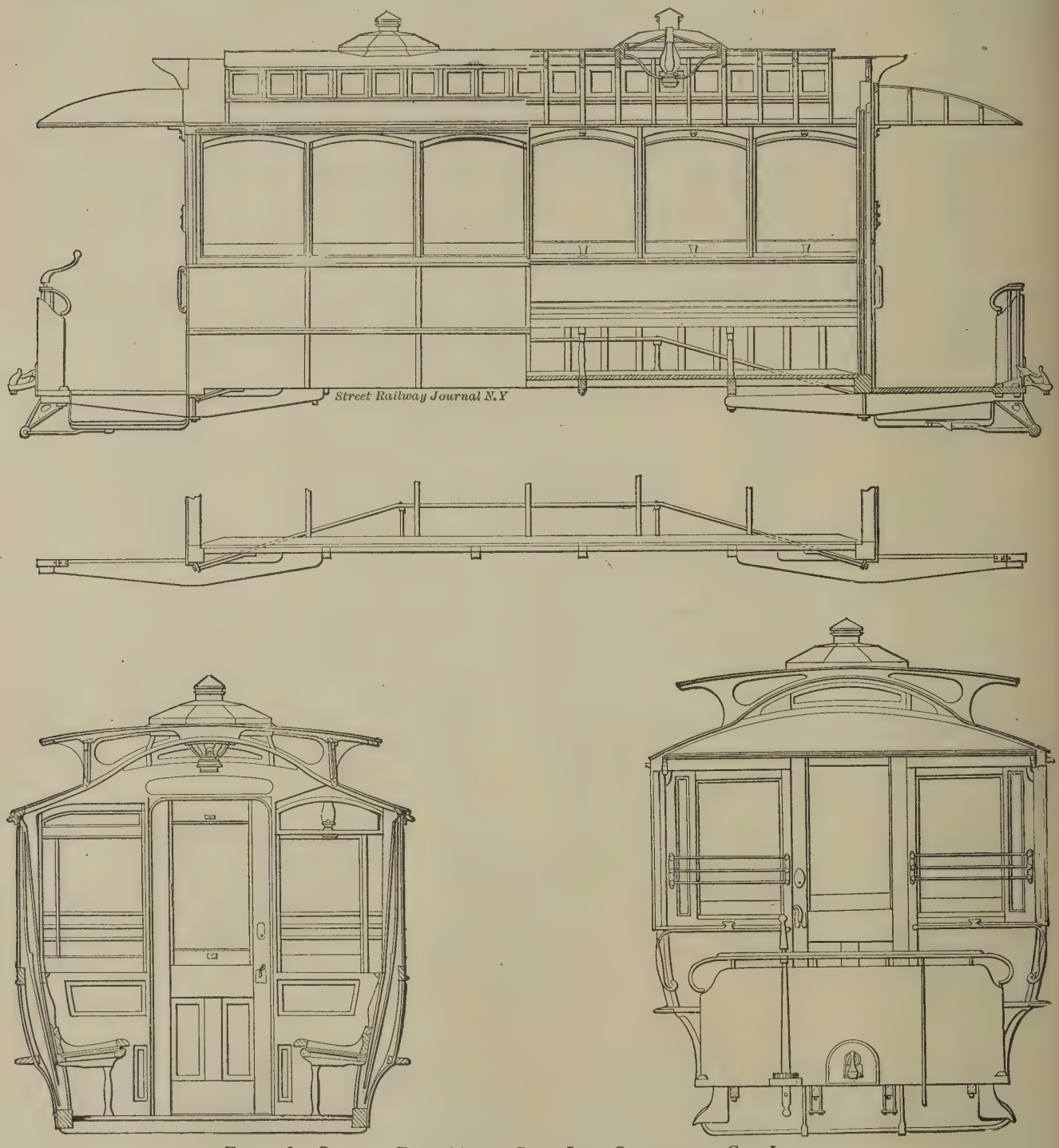


FIG. 408.—SIXTEEN FOOT HORSE CAR—JOHN STEPHENSON CO., LIMITED.

The material ready prepared is now delivered to the erecting shop. The sills, cross ties, bracing, flooring, iron tie rods and angle irons go to the gangs whose duty it is to frame the bottom and lay side sills, two end sills, two first crossings, centre crossings, four longitudes, two cross longitudes, two movable bars, eight platform knees and two crown pieces or platform bumpers (Fig. 402) Yellow

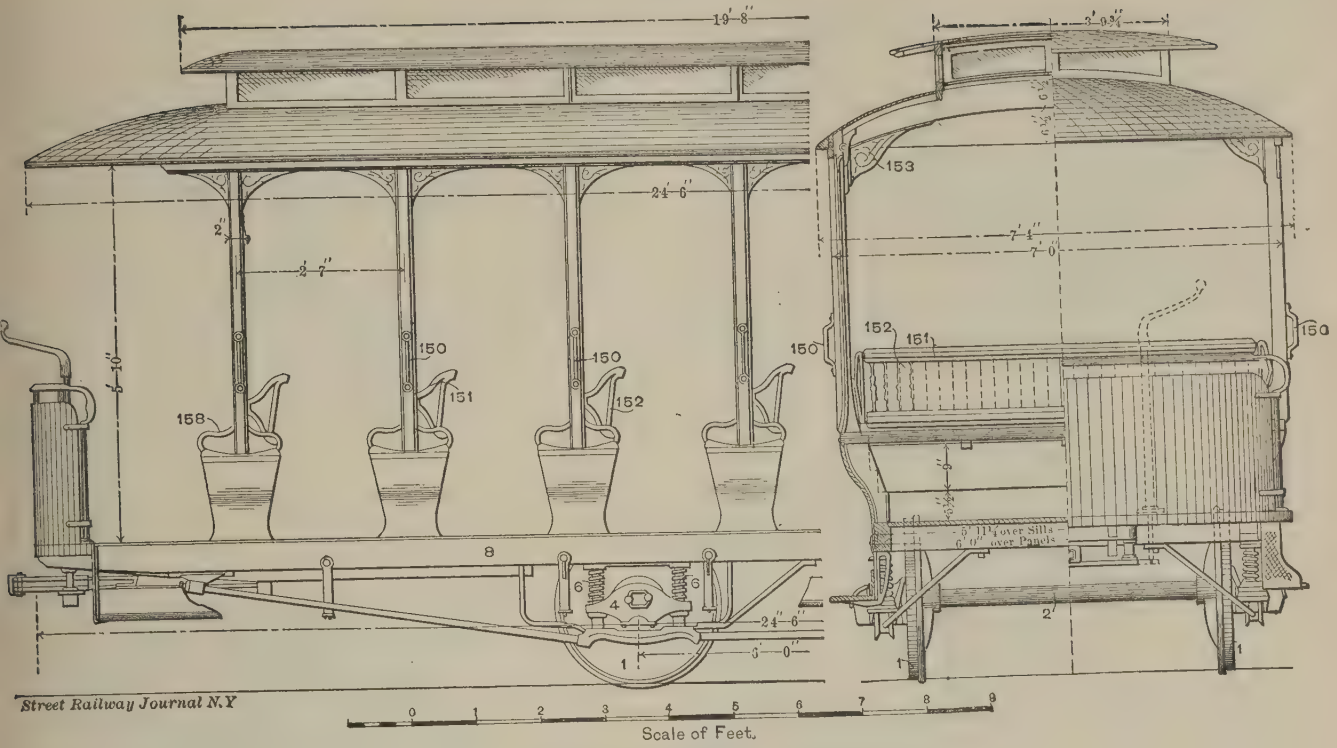


FIG. 409.—OPEN CAR—PULLMAN'S PALACE CAR CO.

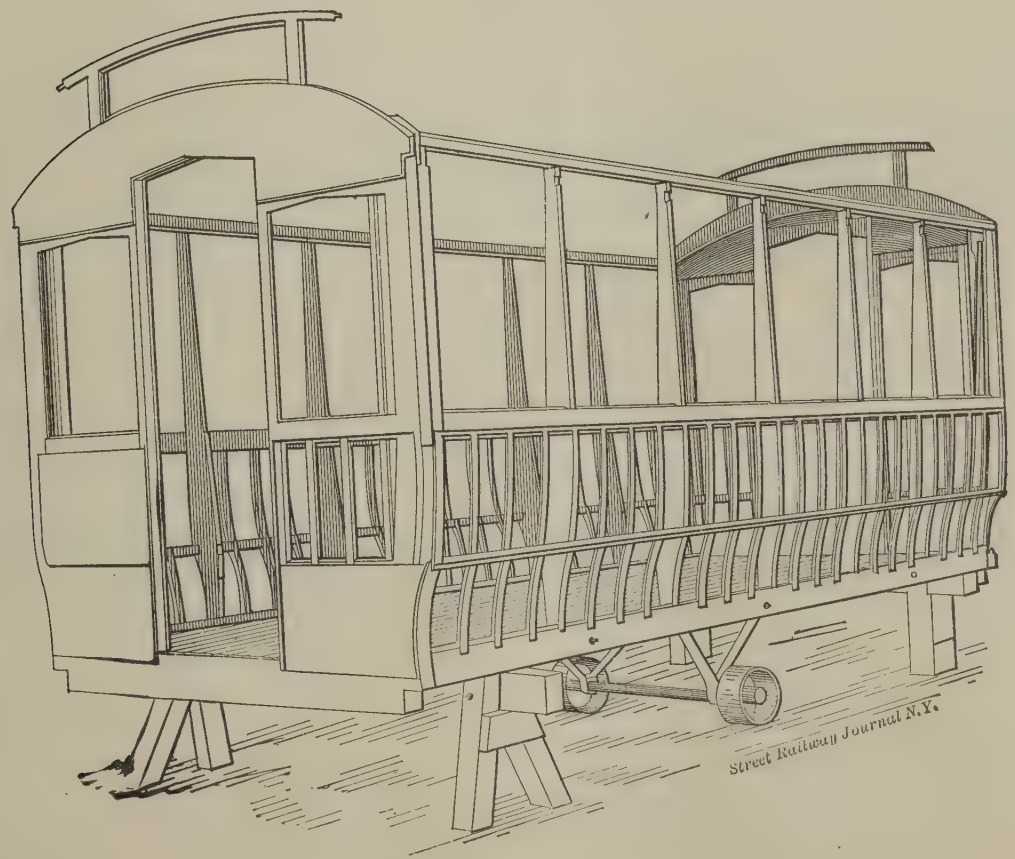


FIG. 410.—CAR FRAME ON STOCKS.

pine is usually employed for the side sills and flooring. Oak is also used for side sills, and, usually, for the cross and end sills, although ash is sometimes employed for cross sills, and the crown sill of the platform is sometimes made of elm. The side sills are usually 4×5 ins., and on long, open cars the sills are sometimes strengthened by the addition of a thin steel plate bolted to the outside. The sills of open cars, when of yellow pine, are sometimes veneered with a light colored wood which offers a better surface for paint. The end sills are of the same dimensions as side sills, and are laid flatways and framed to lap on the side sills or mortised in. All mortises and tenons should be

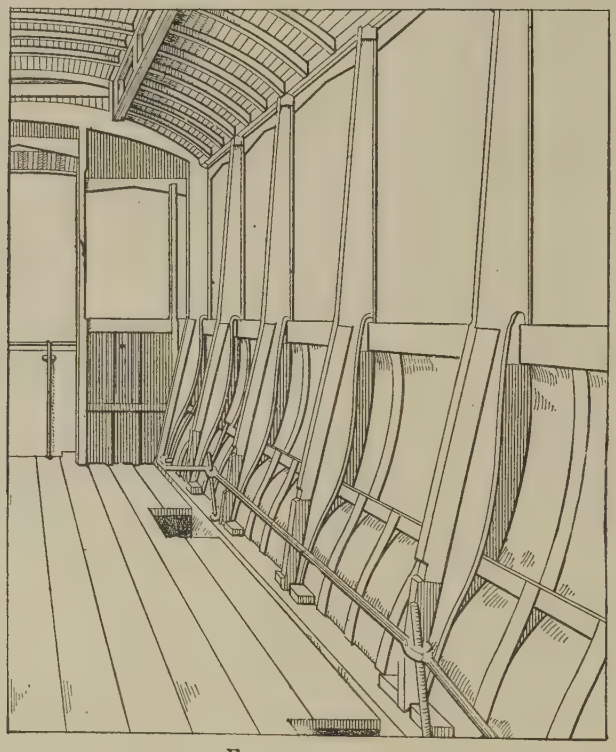


FIG. 411.

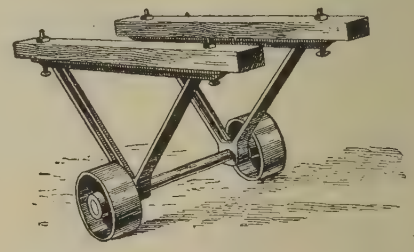


FIG. 413.—TWO WHEEL SHOP TRUCK.

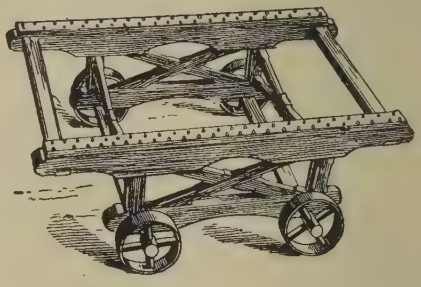
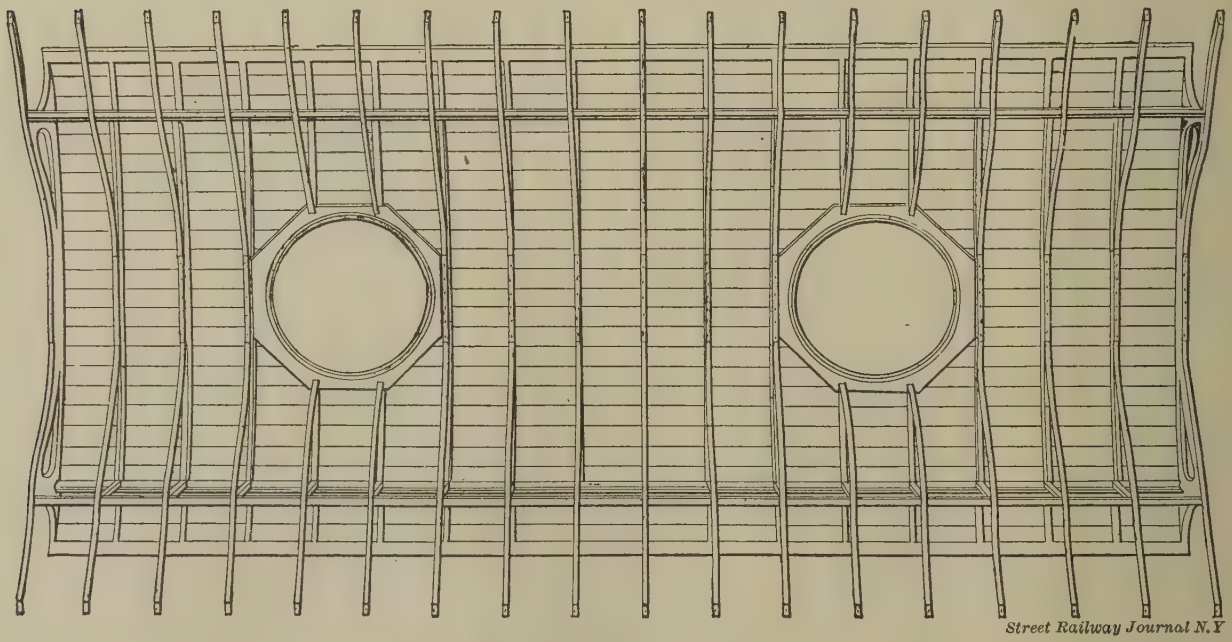


FIG. 414.—FOUR WHEEL SHOP TRUCK.



Street Railway Journal N.Y

FIG. 412.—BOMBAY ROOF.

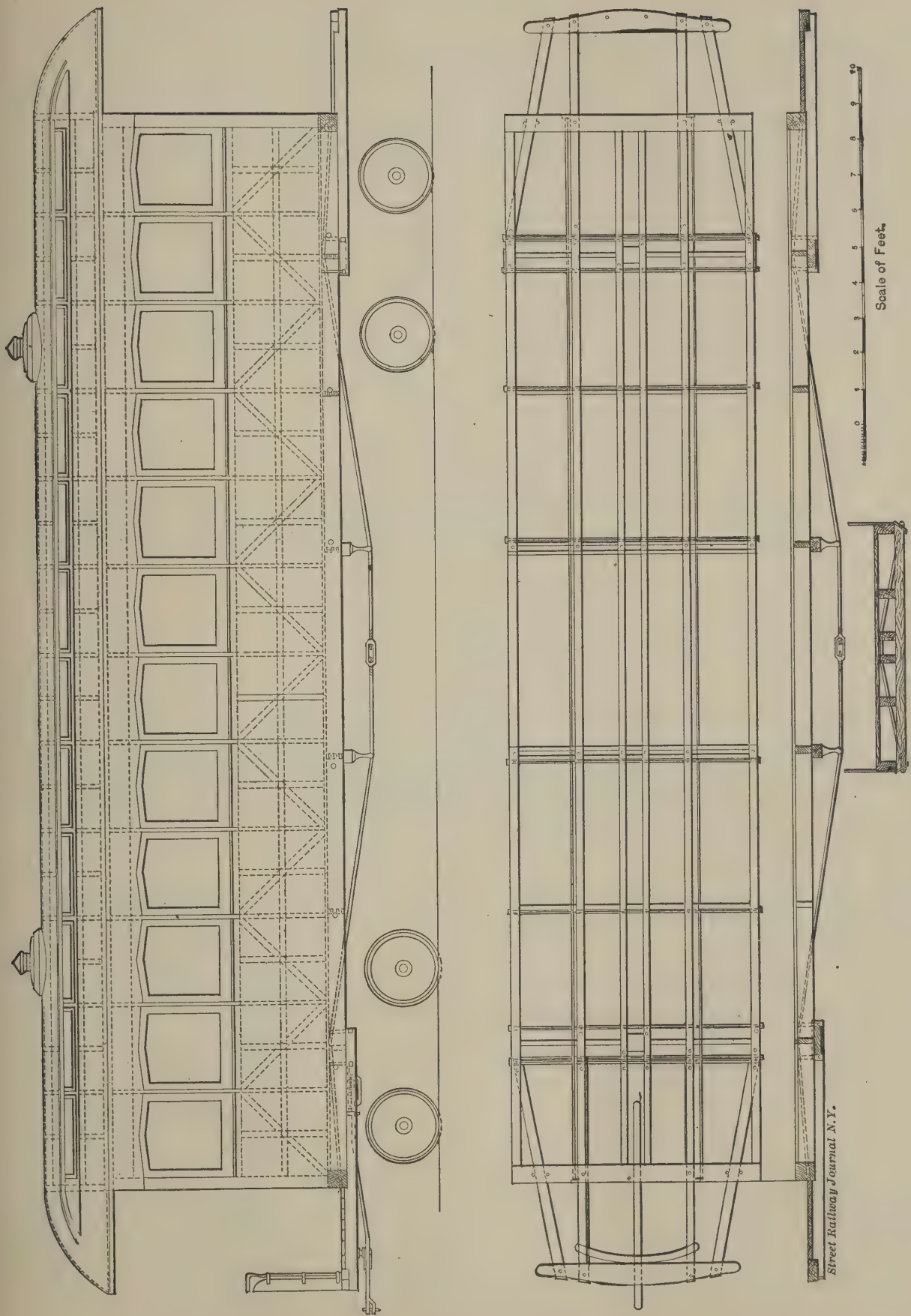
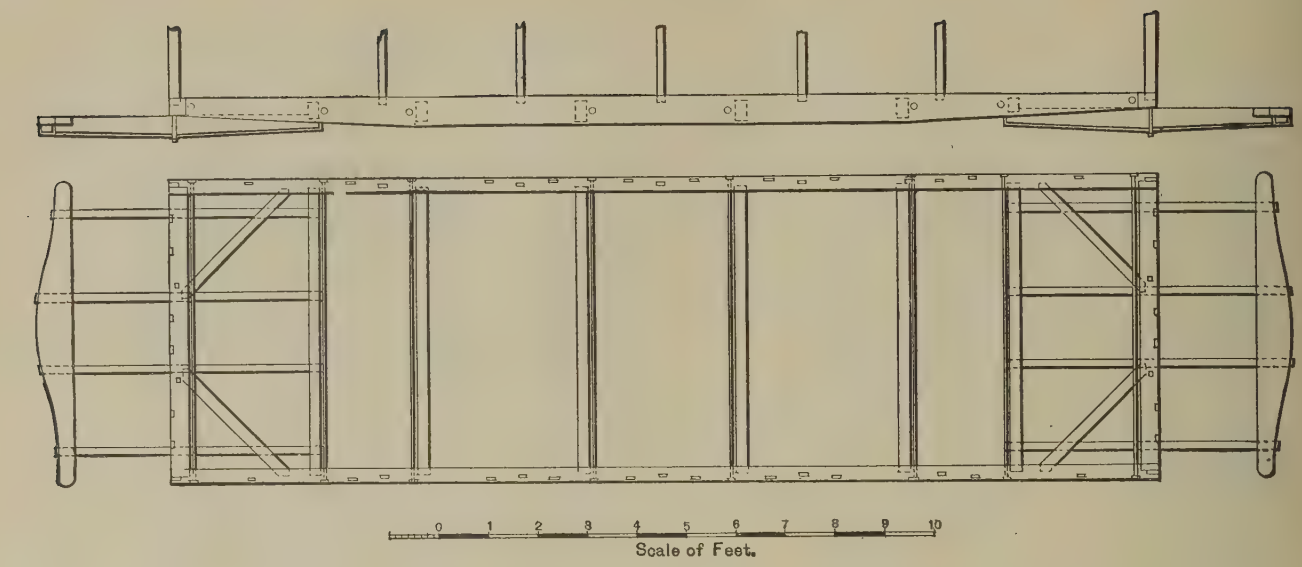
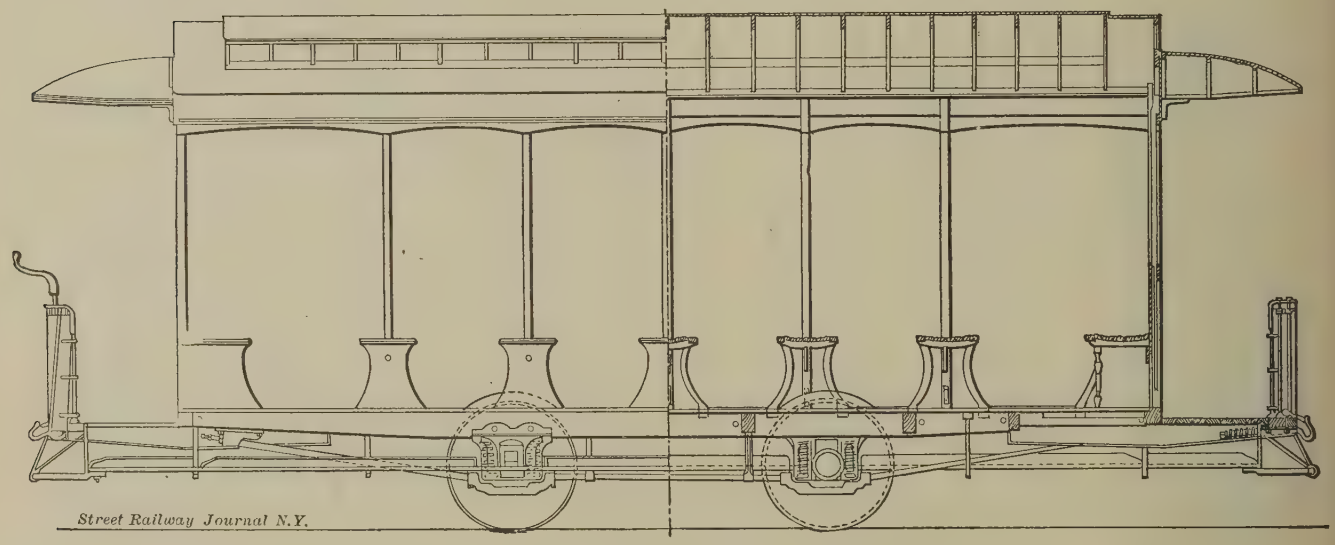


FIG. 415.—EIGHT WHEEL CLOSED CAR—LEWIS & FOWLER MANUFACTURING CO.





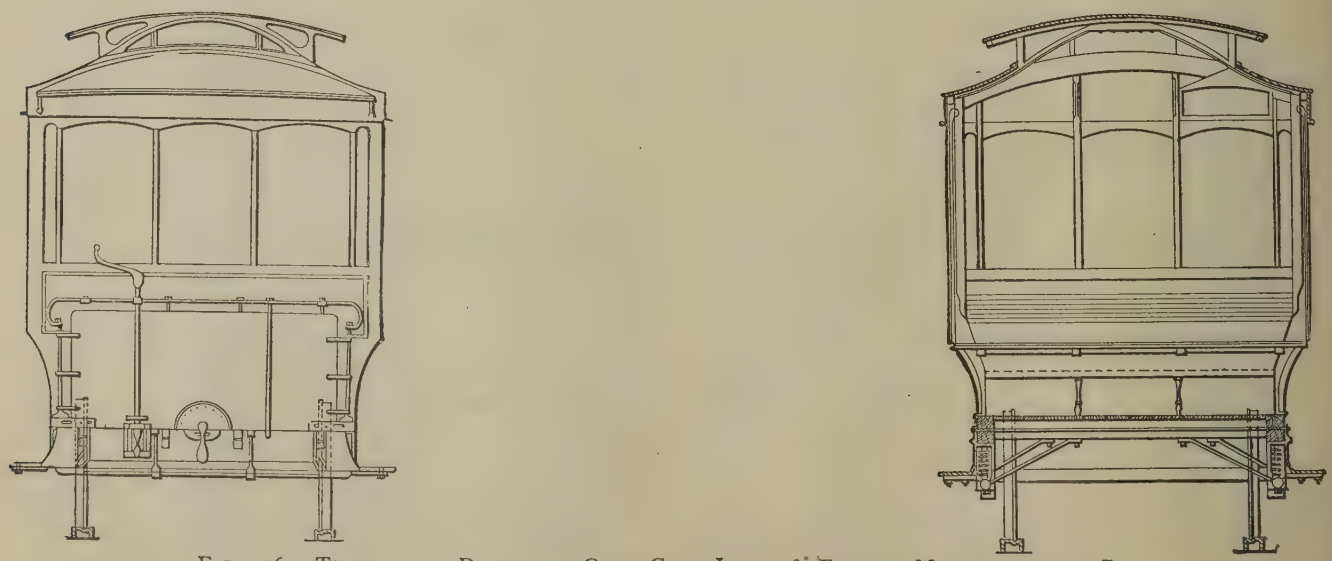


FIG. 416.—THIRTY-FIVE PASSENGER OPEN CAR—LEWIS & FOWLER MANUFACTURING CO.

covered with white lead to prevent the access of moisture. The cross or middle sills may be framed to lap the side sills or may be mortised. The middle crossing should be the heaviest and have a tie rod through the centre. Tie rods also connect the side sills at the intermediate crossings, and short tie rods connect the side sills with the longitudinal timbers. The platform knees, usually of ash or oak and strengthened sometimes with steel plates, should lap the first cross sill. Hickory is sometimes employed for platform knees, but is not recommended as it is subject to decay, and if bent by heavy loads will not resume its original form. The cross framing should be ar-

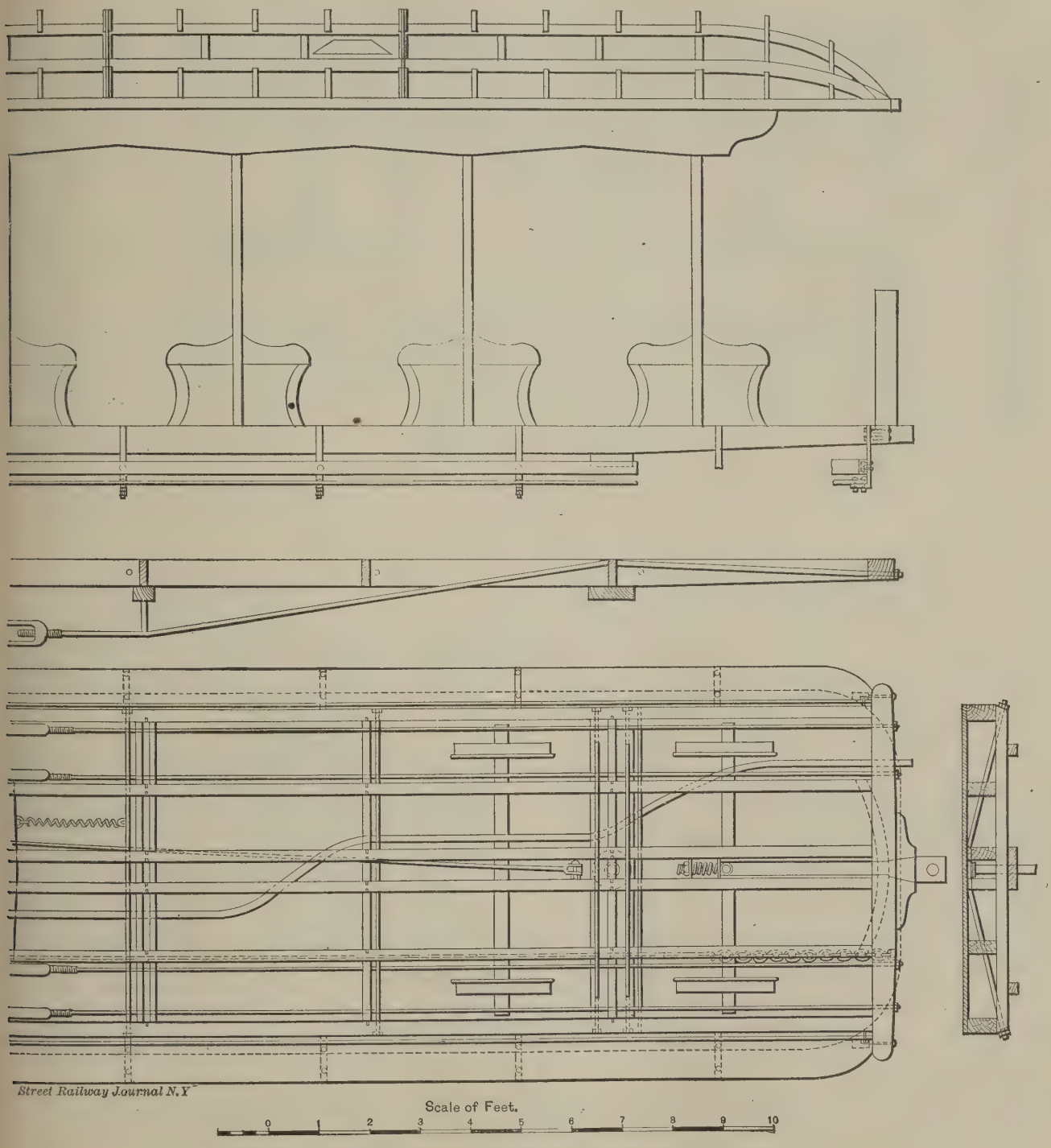


FIG. 417.—EIGHT WHEEL OPEN CAR.

ranged to provide for traps in the floor to give access to the motors. The traps may be hinged so as to turn up or they may be lifted out altogether. If built quite long the same form of trap will suit a number of different motors. If we were building a long eight wheel car the framing would be different, and the traps would come at each end of the floor. It is quite important, before designing the floor framing for electric cars, that the type of truck to be employed should be specified, as the diameter of wheels, wheel base and dimensions of trucks vary so much, that the framing for one will not suit another.

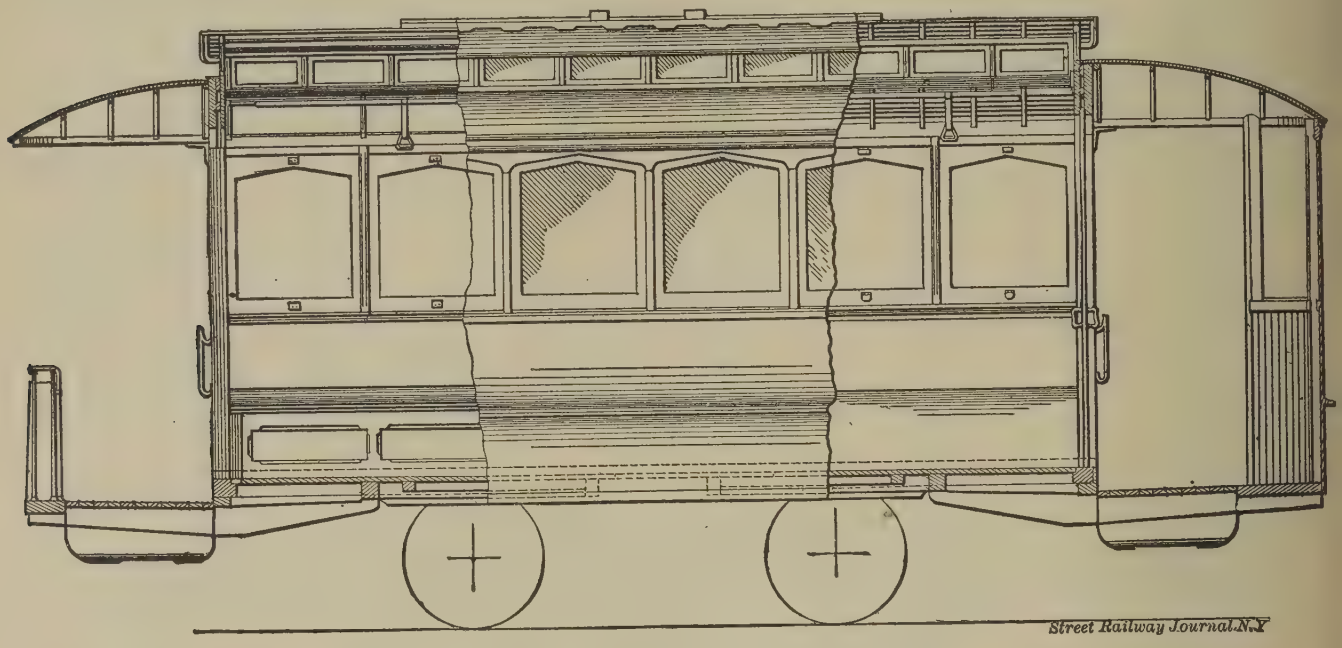


FIG. 418.—STANDARD SIXTEEN FOOT CAR—J. G. BRILL CO.

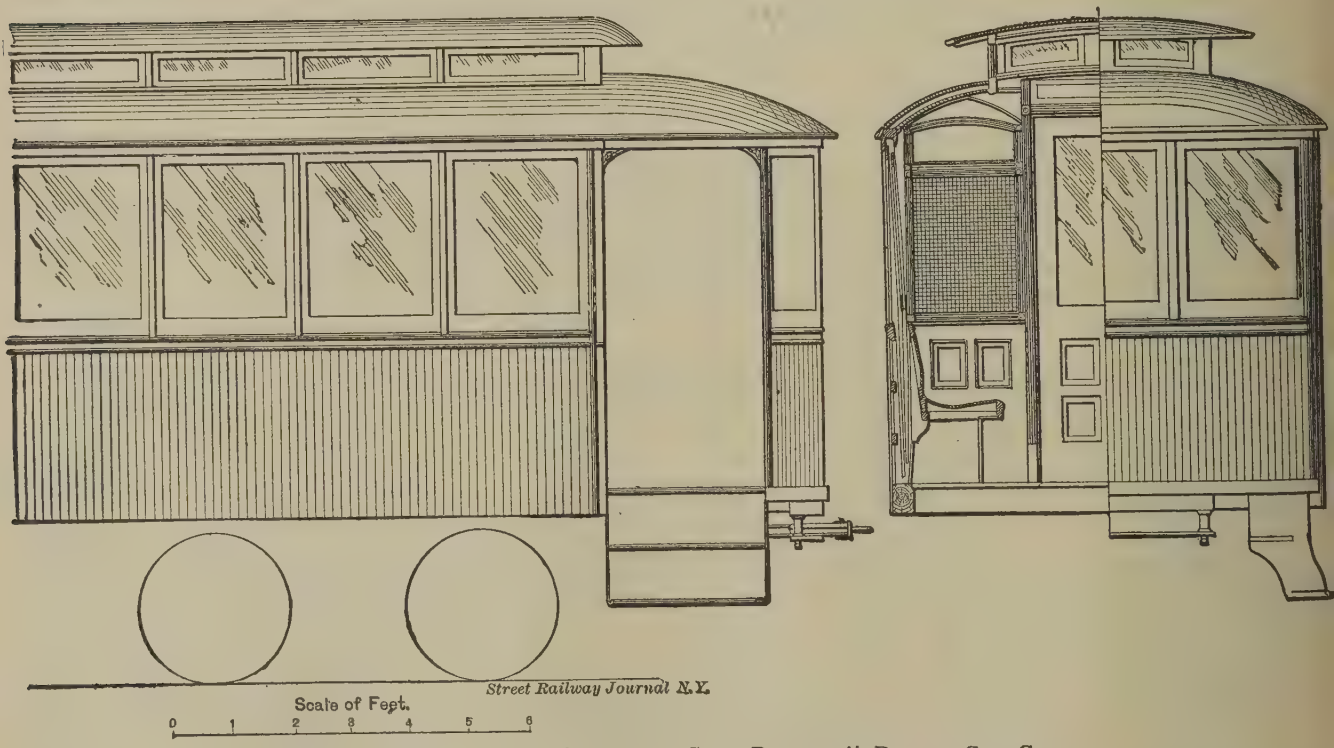


FIG. 419.—EIGHT WHEEL VESTIBULE CAR—PULLMAN'S PALACE CAR CO.

For flooring, hard pine or maple boards may be

employed. The material should be straight grained and free from knots. It is usually dressed on one side to about seven-eighths of an inch in thickness, tongued and grooved or jointed and fastened with screws to the cross ties and braces, all the top surfaces of the latter having first been given a coat of white lead. It is also a good practice to give the under side of the floor a coat of mineral paint. The platform knees and end timbers or crown pieces are conveniently put on by turning the frame upside down. This is not necessary, however. The crown pieces should be two or three

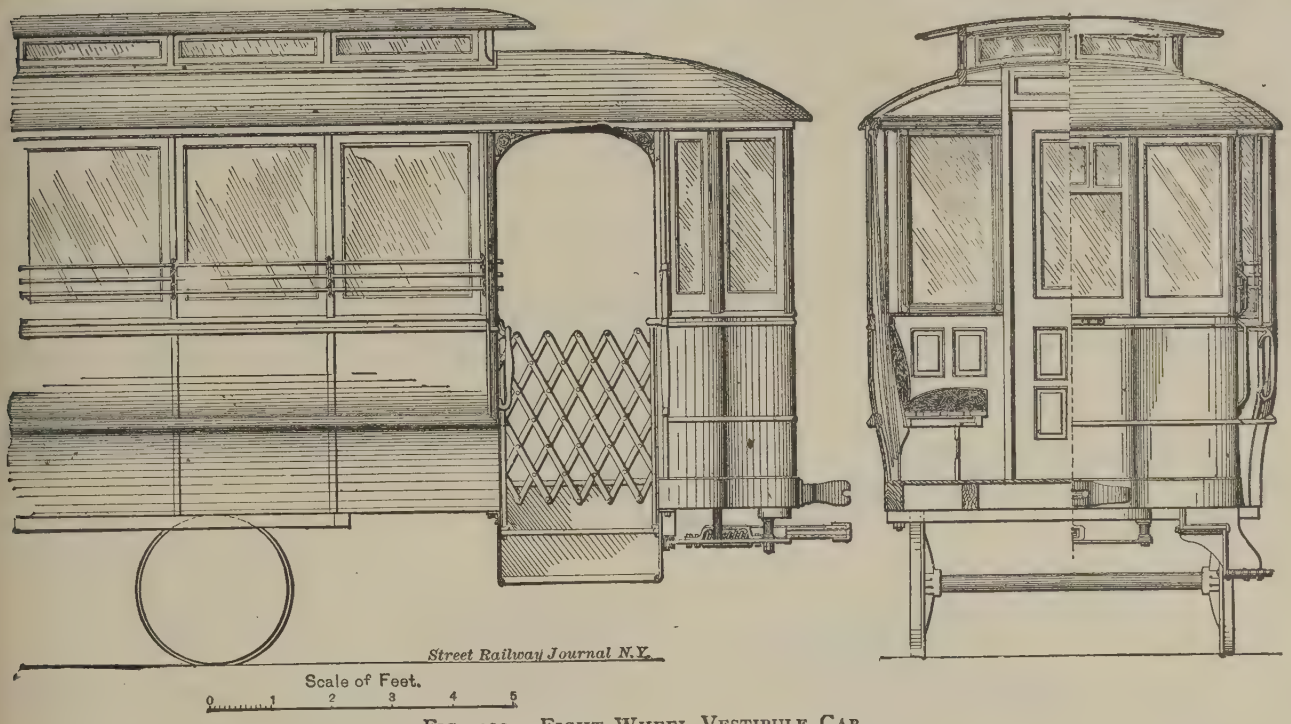


FIG. 420.—EIGHT WHEEL VESTIBULE CAR.

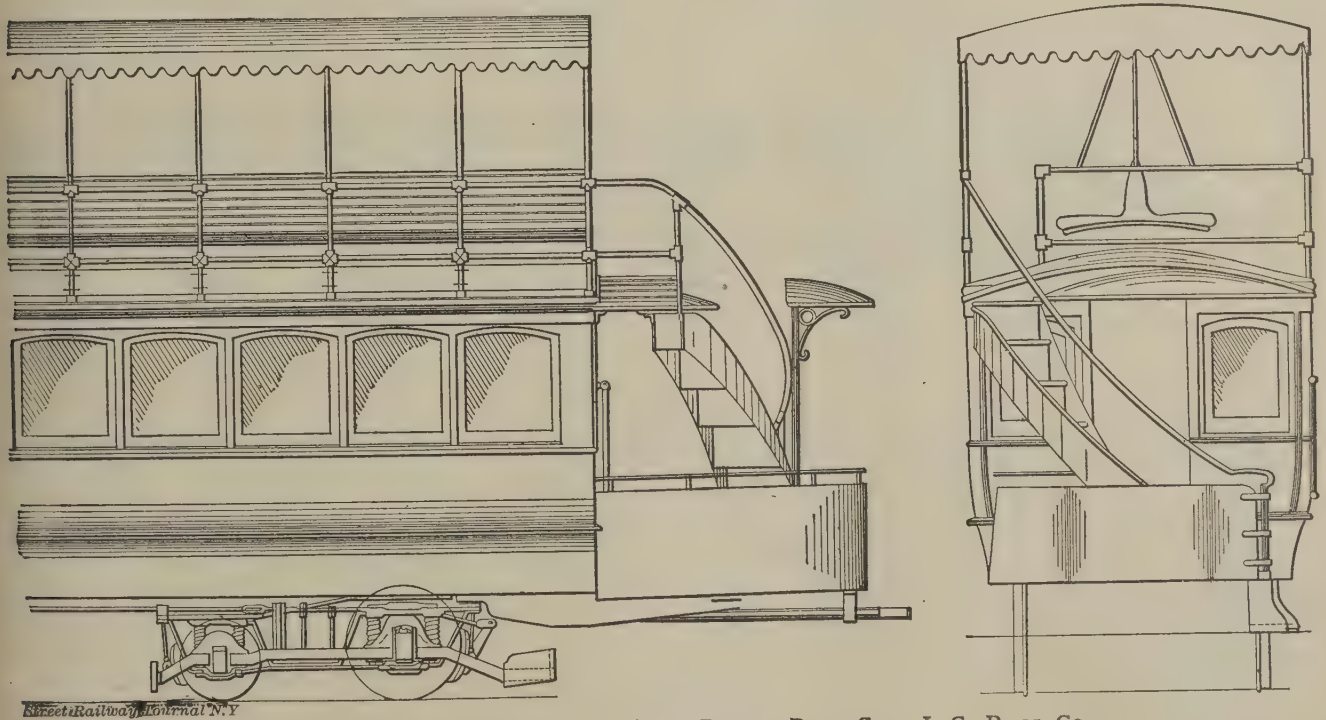


FIG. 421.—TWENTY-FIVE AND A HALF FOOT DOUBLE DECK CAR—J. G. BRILL CO.

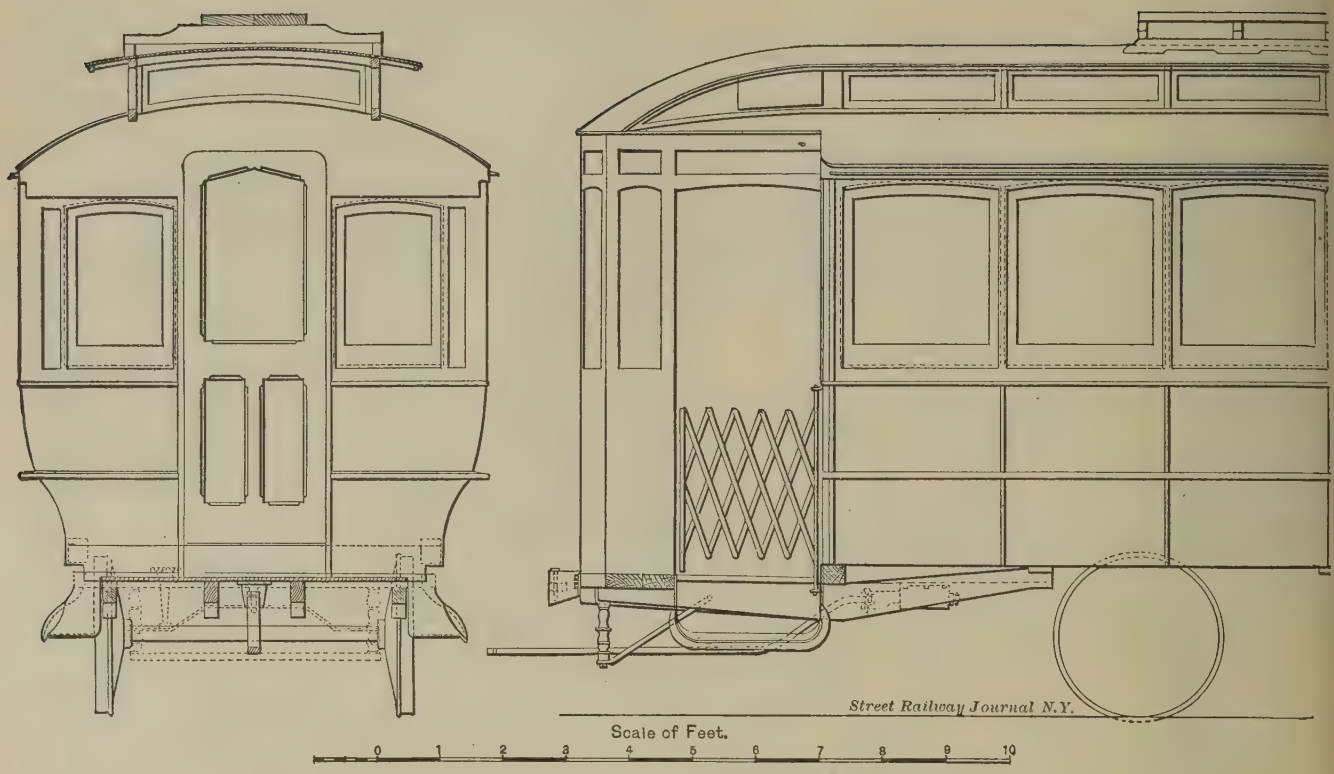


FIG. 422.—SIXTEEN FOOT VESTIBULE ELECTRIC CAR.

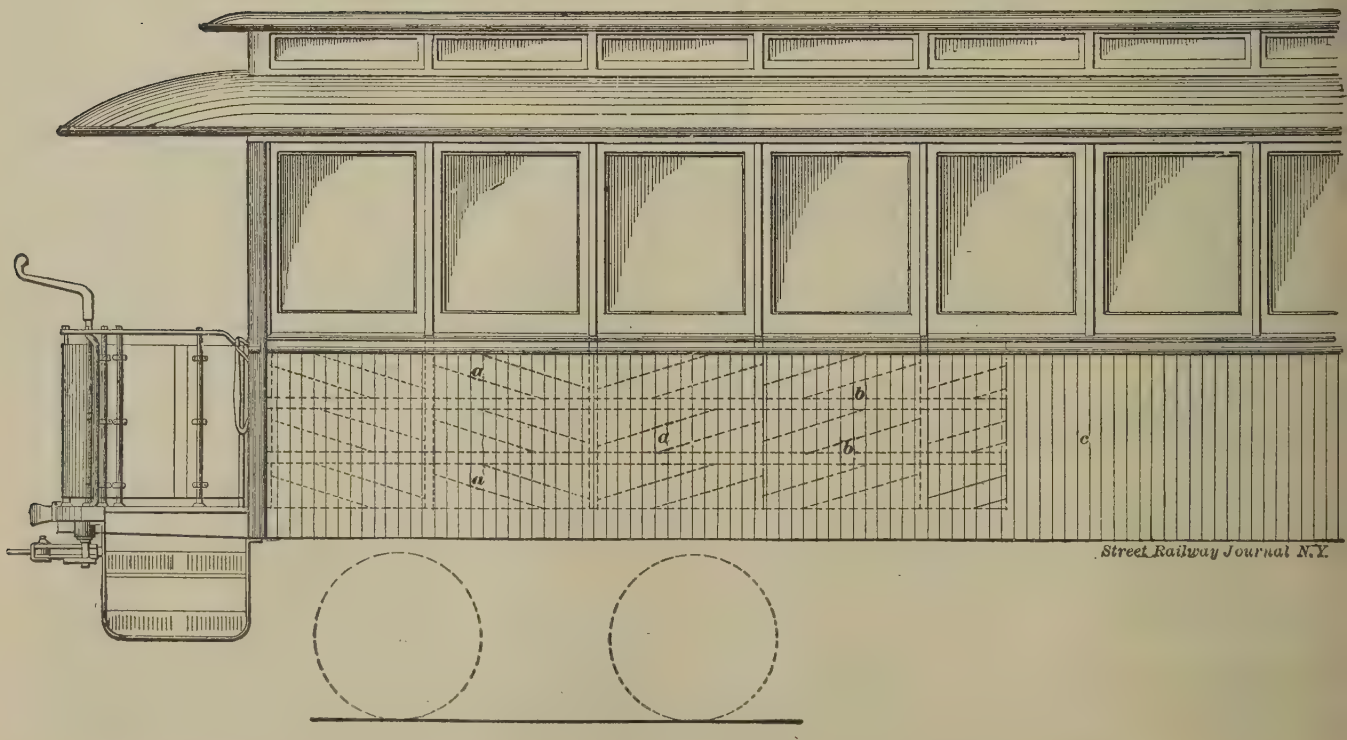


FIG. 423.—EIGHT WHEEL CLOSED CAR—TRUSS RODS OMITTED.

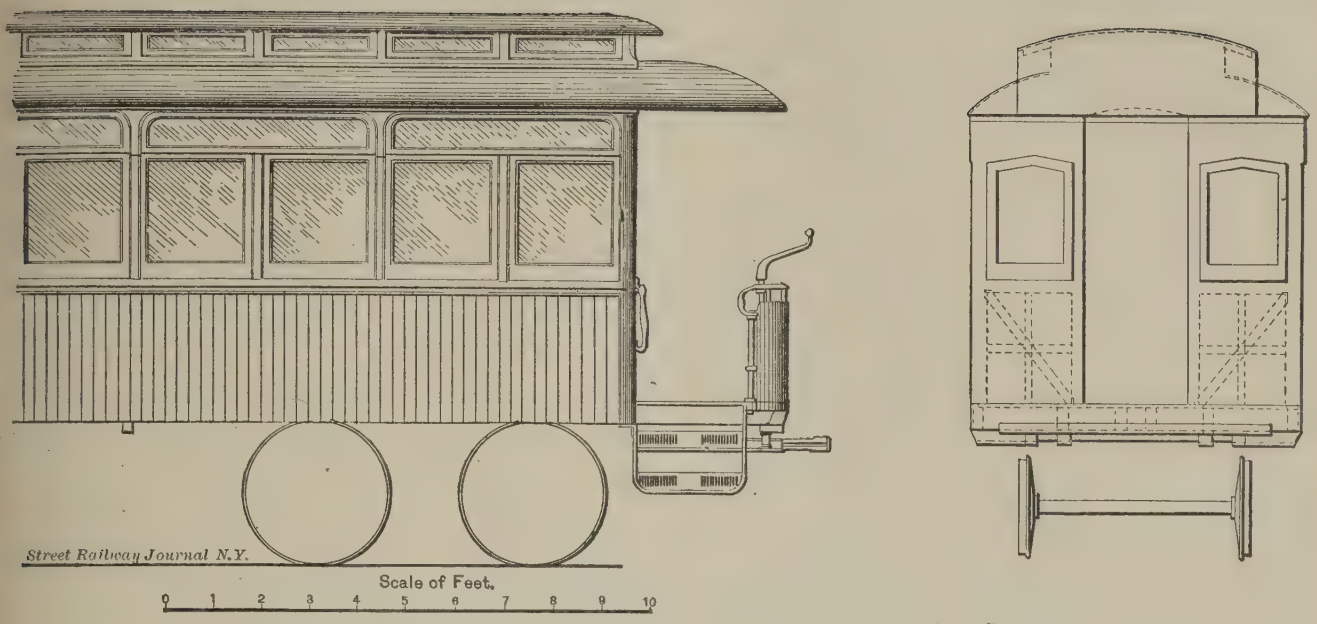


FIG. 424.—EIGHT WHEEL CLOSED CAR—PULLMAN'S PALACE CAR CO.

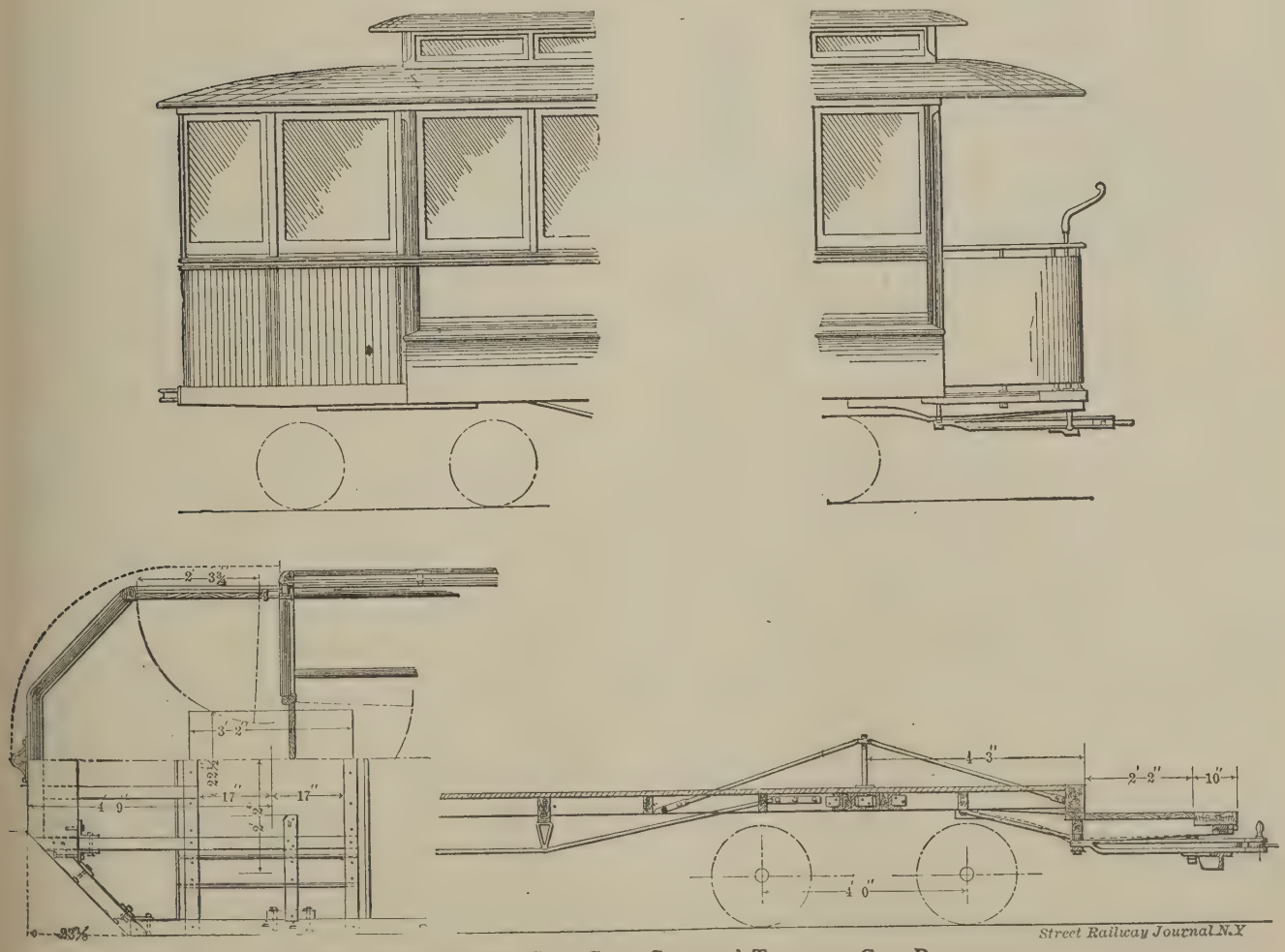


FIG. 425.—EIGHT WHEEL GRIP CAR—CITIZENS' TRACTION CO., PITTSBURGH

inches thick, and of sufficient length to come out as far as the side sills of the car, and the outside knees

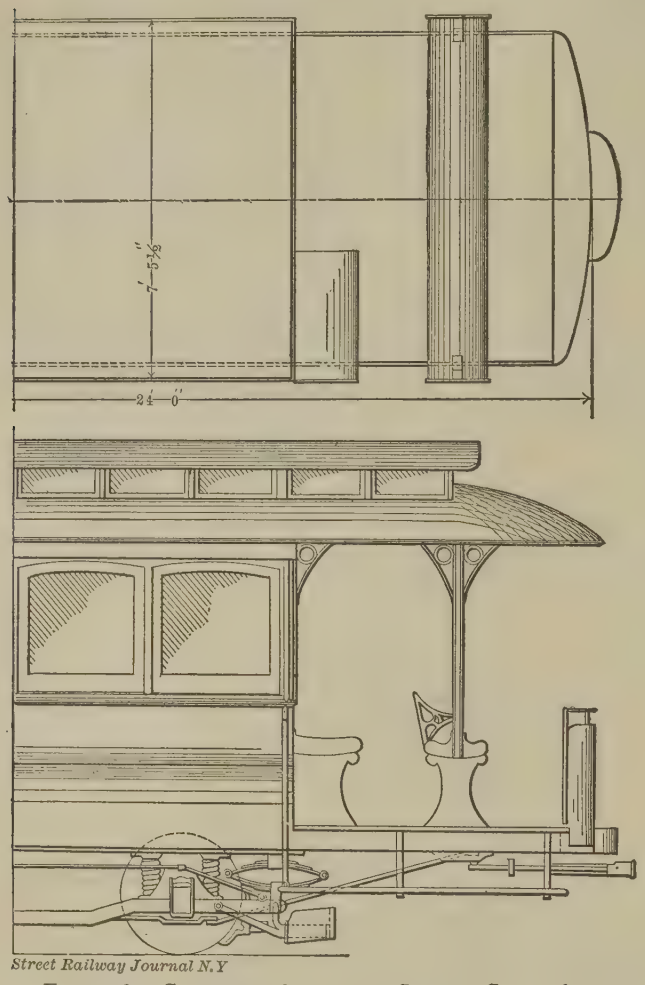


FIG. 426.—COMBINED OPEN AND CLOSED CAR.—ALSO BUILT WITH A DOUBLE DECK.

should be set back far enough to make room for the side steps, and also spaced to provide for placing the rheostat under the platform if one is to be employed. Fig. 407. The platform is usually so connected that it may be detached from the body. The platform floor is commonly laid with oak, but may be of the same material as the car floor.

The platform is now delivered to the body builders where it is supported, preferably, under the middle by a low two or four wheel truck, (Figs. 413 and 414), upon which it can be moved about the shop as the work progresses. Low horses, a trifle higher than the truck, are placed under each end so that the frame will sag a little in the middle, as it helps to strengthen the car and prevent the ends when finished from drooping, as they are liable to do with heavy loads, if built straight and mounted upon trucks with a short wheel base.

The side posts (pillars, Fig. 405), which have previously been grooved by machinery to provide runs for the window sash and blinds, are next set up in mortises cut in the side sills, all mortises and joints being covered with white lead before the union is made. These posts are usually of ash (dark colors being employed for closed cars and light colors for

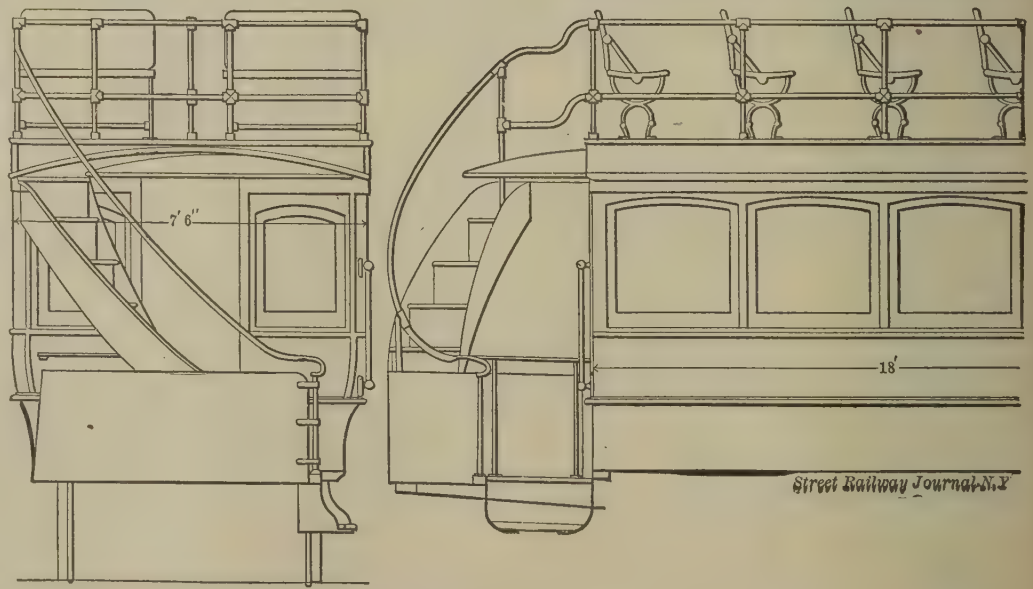


FIG 427.—DOUBLE DECK, CENTRE AISLE CAR—J. G. BRILL CO.

open cars), one and one-eighth inches to one and one-half inches thick. Being set in the mortises they are firmly held in place by strap bolts which come up through the sills with the strap portion extending up several inches on the inside of the lower end of the post. The corner posts come next, and these should be $3\frac{1}{2} \times 5$ ins. at least (Fig. 406). Door posts should be heavy enough to allow of a groove down the centre for a tie rod which fastens the head rail and pillars down to the end sills, and a groove for the electric wire which leads through to the roof. The end may be put together on the bottom of the car and then raised into position.

Erect temporary scaffolding on which to stand and put on the plate, and fasten stretchers across the top, making the sides the same width at the top as at the belt rail. Square everything true and put on the belt rails which are commonly halved on the posts. The work on the belt rail, if laid out from the mortises in the sills, will bring the space between the posts of the same width all the way up. Add the convex and concave ribs, according to the curvature of the sides, then the drip rail and the letter board. The sash rails, light rails, strainer rails, straight ribs and head rail of the ends are next added and primed, when the frame is made ready for the panels. These are usually made of white wood and, having previously been bent to the proper shape and dried, are put in place and blocked, the lower outside first, after which the ends of the car are panelled up, care being taken that the panels are all up to the ribs. The whole inside is then covered with scrims put on with hot glue and painted, when it is left all night to set. Next morning the panels are all dressed off and sandpapered, when the painter gives them a coat of oil priming and the work is left to stand over night. The truss rods are now added, when the braces and stretchers are taken out and the car is ready for the roof.

The truss rods may be anchored as shown in Fig. 403, or in Figs. 407 and 408. In some shops a different method of construction is followed for long double truck cars, which is designed to do away with truss rods. As shown in Fig. 423, the bracing consists of angle pieces of boards (*a*) bearing partly on the side posts, sash rests and side sills, and secured by glue and clinch nails to longitudinal pieces (*b*) of the same material. The longitudinal pieces extend the full length of the car and have a shoulder rest on each post by means of a groove one-eighth of an inch deep. The outside sheeting (*c*) consists of narrow pieces of boards put on vertically, with white lead in the joints and glued and nailed to the longitudinal pieces. Before applying

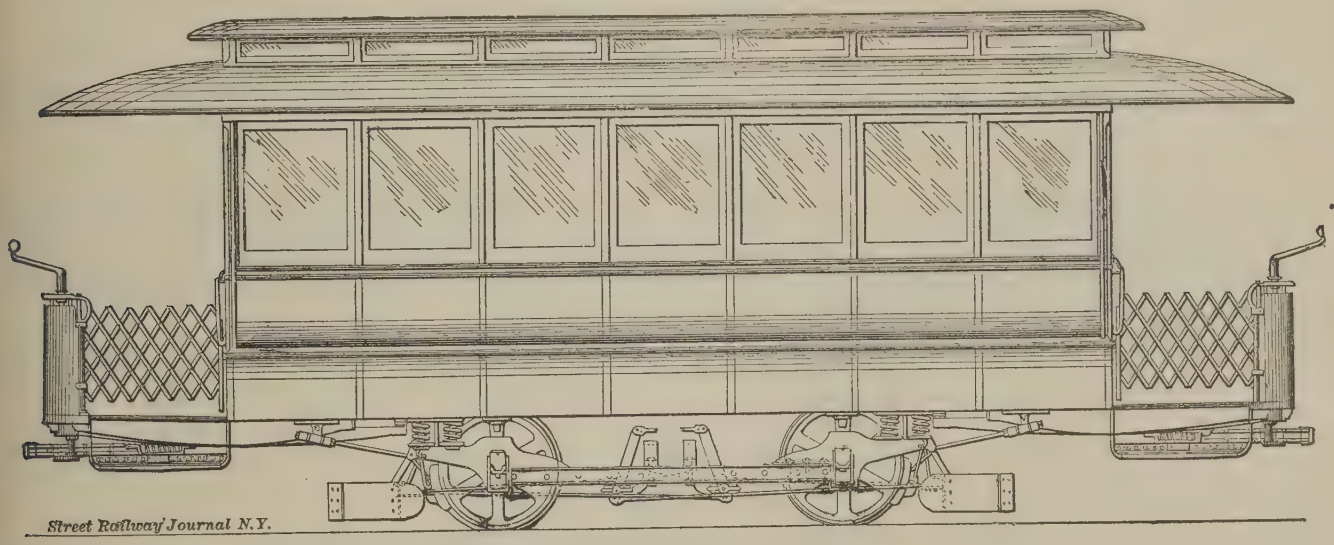


FIG. 428.—CLOSED CAR.

this trussing the middle of the car should be slightly arched, and when completed this construction will have great strength.

The roof, which may be made plain or after some one of the monitor or Bombay types (Fig. 412), is usually prepared in the cabinet shop, or may be made by the body builders who work on it at intervals. The frame, which may be of ash or oak, depending upon the proposed inside finish, should be strong, with from three to five compound carlines to support the weight of the trolley stand and prevent the sides from bulging. Compound carlines are usually made of flat wrought iron or steel strips which, being reinforced on each side with half round wood, bolted through, or methods of roof framing, which make a very substantial construction, or remove the weight of the trolley from the central portion of the car roof.

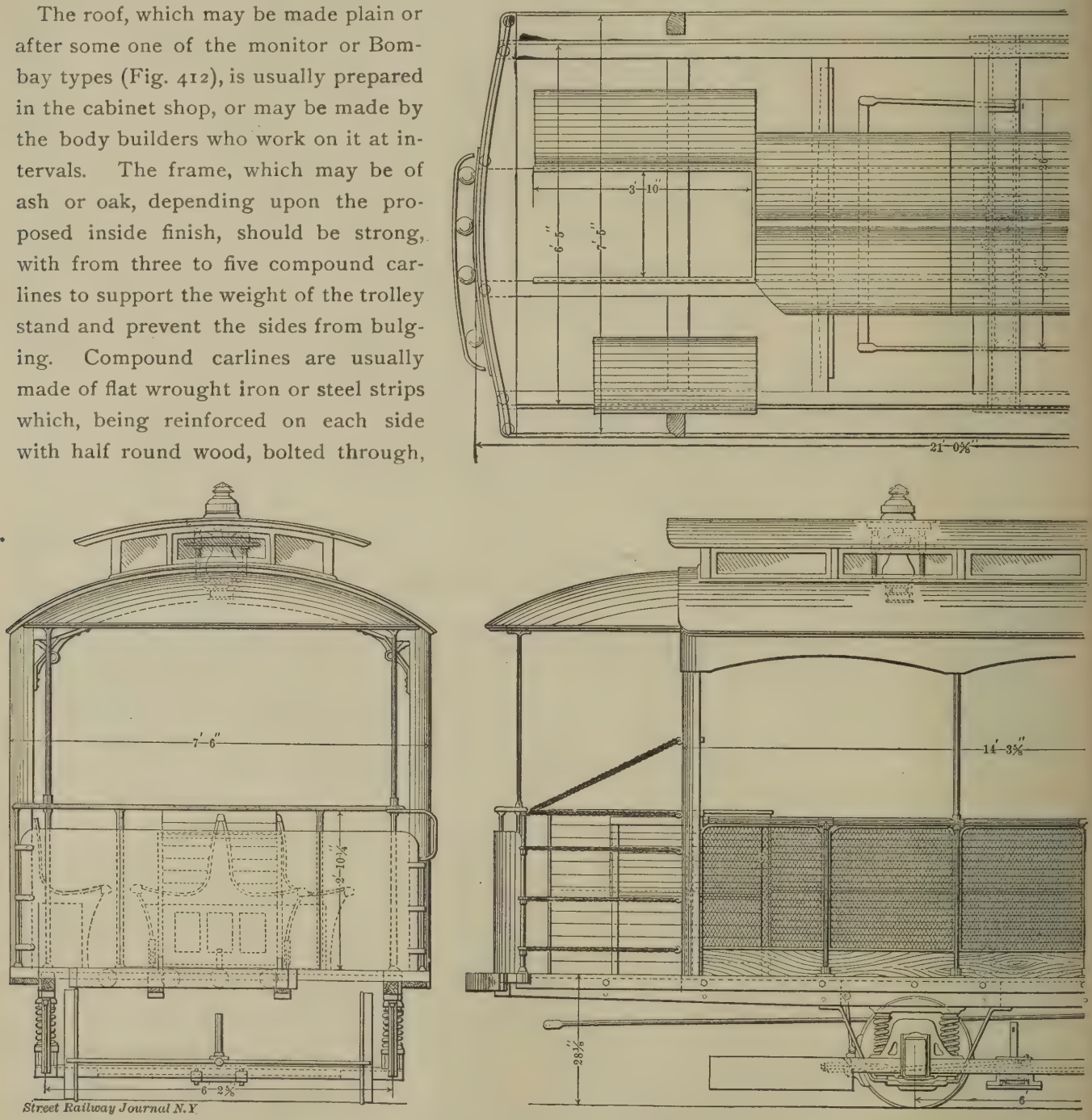


FIG. 429.—OPEN GRIP CAR—J. G. BRILL CO.

have the appearance, when finished, of the ordinary wooden carlines. Compound carlines do not in all cases prevent the roof from settling, or sides of the car from bulging; hence, certain builders adopt some of the well known patented devices

One method employs a wide board, slightly arched, extending the length of the body, with the ends resting on metal straps, which are attached to the end of a tension rod, blocks being inserted to keep the compression and tension members of the

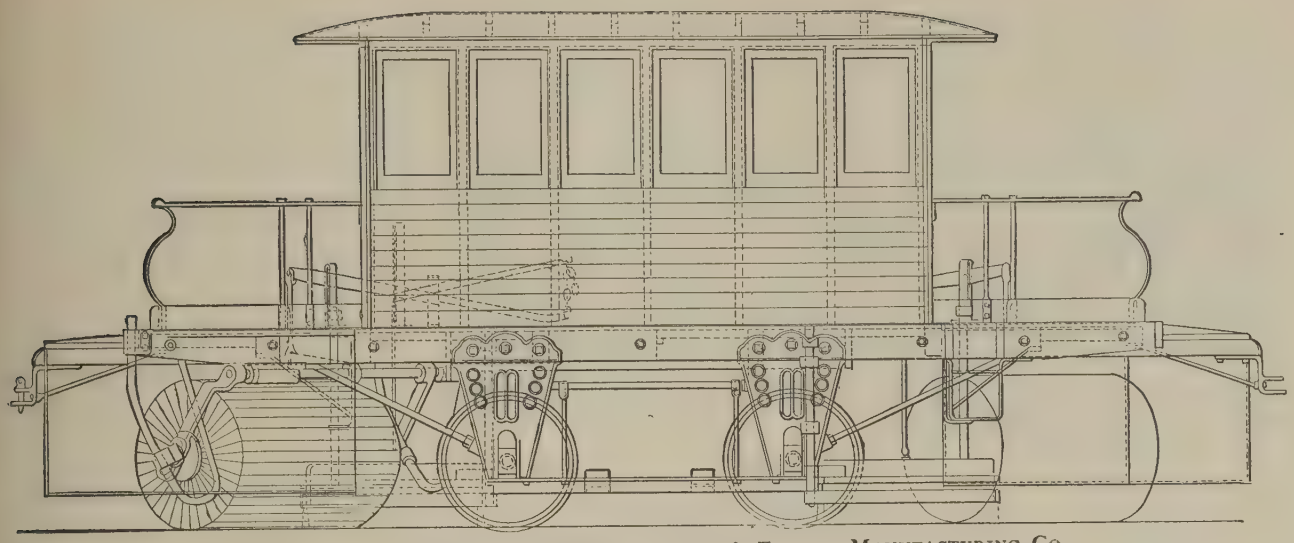
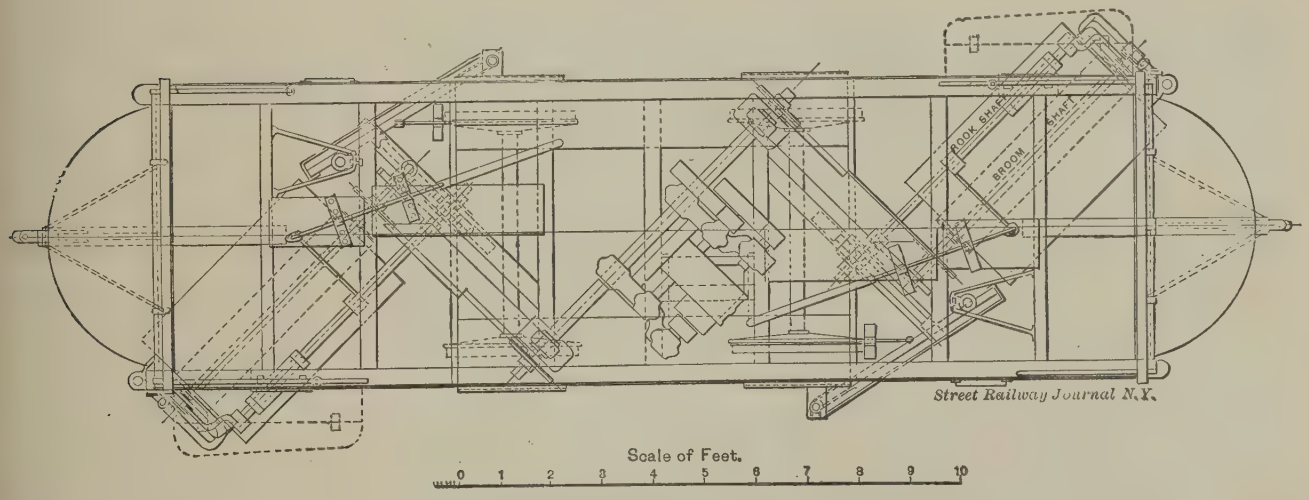


FIG. 430.—ELECTRIC SNOW SWEEPER—LEWIS & FOWLER MANUFACTURING CO.



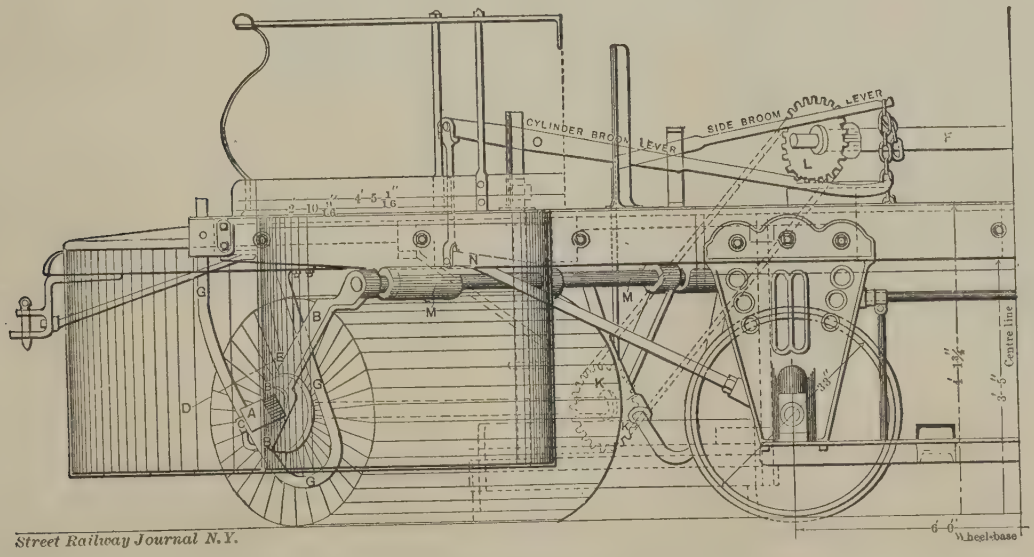


FIG. 431.—ENLARGED SECTION OF FIG. 430.

truss at proper distance apart (Fig. 434). Another method consists in framing the ventilator rails and uprights in an arched form which is strengthened by means of truss rods running from end to end of the car immediately under the bottom ventilator rails (Fig. 435). A third method which is designed to relieve the roof from the weight of the trolley is shown in Fig. 433, and consists in placing two thick planks parallel to each other above the roof and supporting the ends on rubber bearings above the end framing.

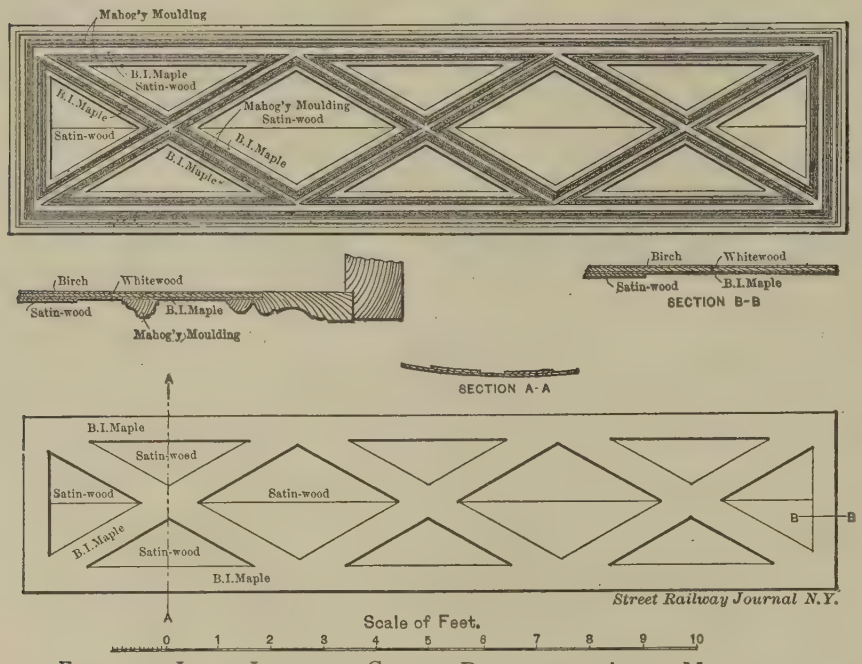
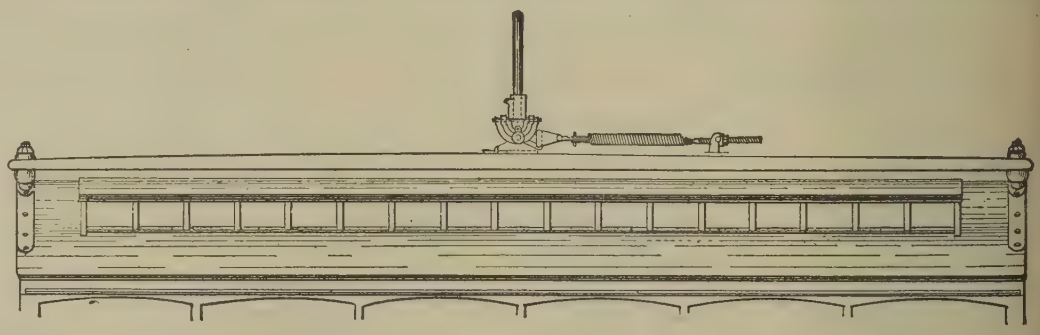


FIG. 432.—INNER LINING OF CEILING BEFORE AND AFTER MOULDING.

The roof covering may consist of half inch ash boards, bevelled or rounded on the under edges, or of three-ply veneer, depending upon the proposed inside finish. Oak or birdseye maple veneer, firmly fitted on top of the carlines, makes a very strong roof for carrying the trolley stand, and being decorated makes a fine inside finish, especially where oak carlines are employed to match the oak veneer. The roof being in place, it is slightly shored up in the middle, when the ends are fastened to the head rail, and the carlines to the eaves-plates which have been previously mortised to receive them. The edges are then dressed off, when the roof is given a priming coat, the nail holes filled with putty, and after drying, the roof cloth, which consists of heavy canvas (laid in white lead), is put on, stretched very tight and tacked under the outer edges. The eaves moulding is then put on and the car is ready for the hood which is really an extension of the roof over the platforms, but so put on as to be readily removed, for convenience in shipping. In vestibule cars, however, the hood constitutes the roof of the cab and is framed with it. The hood is made on a form in the shop, and covered with a canvas the same as the roof, when it is put up and bolted to the head rail. The water table is then added and the entire roof is covered with a coat of mineral paint or white lead.

The scaffolding being removed, work on the body



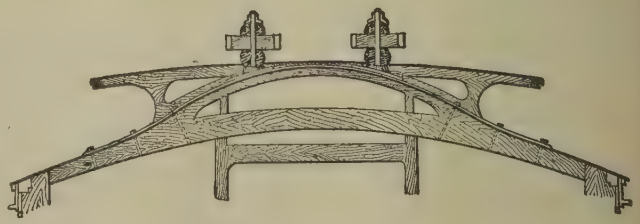


FIG. 433.—TROLLEY STAND.

is resumed. A moulding of half oval iron is next put on over the top panel joint which extends around the corner posts to the door posts. This is usually put on with screws, and the heads being filed off it makes a neat looking job. Next, a fender

rail is added, which is placed over the joint between the upper and lower panels, and being finished with an iron moulding as described above,

FIG. 434.

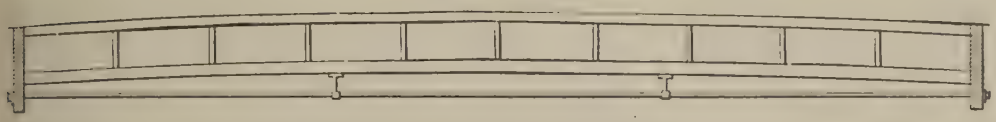


FIG. 435.—MONITOR FRAMING—BROWNELL CAR CO

serves to protect the panels from coming in contact with street vehicles. A plain flat band moulding covers the end joint of the upper panel and a corner iron the joint of the lower or concave panel. One or two flat, vertical mouldings of wood or strap iron on a line with the side posts may be added, which divide the side into panels of different sizes and improve the appearance. The iron dash posts, dashers, brake staffs, bumpers and controlling stand are next put in place and all iron work given a coat of paint. The dashers are usually made of sheet iron or steel, but in some cases wire is employed.

The sash doors and blinds, which have been made in the cabinet department, are next fitted, each to its place, numbered and given the car number, when they are sent to the paint shop for finishing, after which the glass is set and the sashes are rubbed down and varnished.

The overhead and bottom tracks for doors are next laid down, door guards put on, doors hung, head linings fitted, also end linings, heel boards, seat rails, stove box, mouldings and curtain fixtures. Then, all parts being numbered, they are taken out and sent to the paint shop for finishing. To produce a carline finish, in case veneer is not employed for the roof, the ceiling between the carlines is covered with veneer. Oak, birdseye maple and birch veneer is employed, and may be left plain or perforated and decorated. Matched roof boards of different colored woods make a tasty ceiling finish. Sometimes the entire heading consists of veneer, fastened to the under side of the carlines, and brought down to the top of the plates. Ornamental panels of different colored woods are frequently introduced into the ceiling with pleasing effect (See Fig. 432).

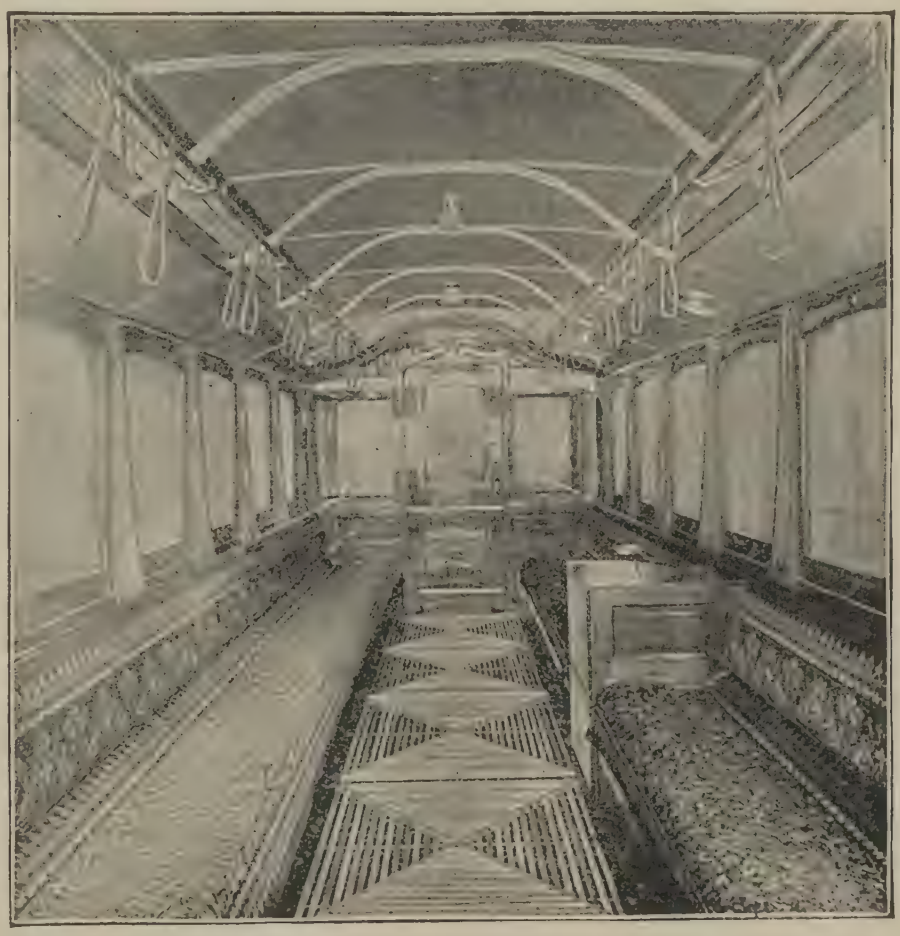


FIG. 436.—INTERIOR OF CAR—JOHN STEPHENSON CO., LIMITED.

The body now goes to the paint shop, where a rough coat is first put on, the entire surface scoured down, and the car is made ready for the electric wires which are put in by experts, which work should be done before the inside finish is applied to the car. The tinners also put in the end lamps and flues, stove pipe thimbles and the piping, if the cars are to be lighted with gas. The sash doors and blinds are now put back and the car is left with the painter to finish and decorate.

PAINTING.

The painting department should be assigned to commodious quarters, carefully partitioned off to exclude dust and insects, and the room should be constructed to provide ample light all around, and, in order to facilitate the work and cause the oil to penetrate deep into the wood, should be warmed in winter to an average temperature of seventy-five degrees. The method of mixing the paints and the time allowed for the different coats to dry, depend somewhat upon the time limit for filling the order and the climate of the locality where the cars are to be put in service. When durability and high finish are sought, time is an important factor. To meet the different conditions we give two methods of practice, the first when haste is important, as in filling large orders, and the second when time is not a condition.

The foreman must keep a sharp lookout for all new work as it advances, and order the priming coat put on before the body leaves the erecting shop, which can be done in an hour, but will often advance the work at least a day. A good priming coat consists of pure lead mixed with two parts boiled oil, one part raw oil, a little elastic japan, and sufficient turpentine to cause it to work freely under the brush. This should be thoroughly brushed into the pores of the wood, care being taken to introduce the color into the nail and screw holes, unless these are too large, in which case they should first be filled with wood buttons glued in, or with a mixture of sawdust and glue. When wood buttons or plugs are employed they should be formed so that the grain conforms to that of the surface filled. Where putty is employed for filling large holes, it is apt to crack and fall out after the car is put in service. After drying, the priming is sandpapered lightly, when the first coat is laid on. This may consist of pure lead (ten pounds) mixed with one pint of boiled oil, one pint of elastic japan reduced with turpentine. All nail and screw holes are now filled with putty, and in doing this care should be taken to so introduce the putty that all the air will be excluded, for should there be a bubble of air confined by the putty it will expand and bulge the surface. To produce a good job the puttying should be done at two operations. At the first, the hole is not entirely filled, but the putty is scooped out with the corner of the knife, leaving it rough and slightly below the surface, to give firm hold to the second filling which is added after the first is sufficiently dry, producing a smooth surface. When this is dry it is rubbed down, and then the second coat of paint (mixed the same as the first) is applied.

Two or three coats of rough stuff, consisting of English or American filling, are next laid on, not over two coats a day, however, and better only one if there is time. When sufficently dry the entire surface is thoroughly rubbed down with pumice stone, or better, with Schumacker's rubbing brick which is manufactured in different grades, fine, medium and coarse. Before rubbing, however, it is a good plan to add a coat of stain as a guide to a level surface. This may be made of varnish and japan, in equal parts, thinned with turpentine, or dry umber, ochre or lamp black may be used, depending upon the color of the rough stuff. After drying for an hour or two the rubbing may follow. After being surfaced and washed, the body should be left at least twelve hours to dry, before the next coat is added.

The surface is now ready for its final color. If this is to be a transparent color the surfaced panels must receive a preparatory coat which should be as near the desired color as possible. If it is to be finished in an opaque color this can be applied at once, and consists usually of a japan or quick drying color which is laid on in two coats and followed with clear varnish, or color and varnish.

The surface being flattened, it is prepared for striping, lettering and ornamenting. The designs for letters and outside decorating may first be drawn in outline, full size, on heavy manilla paper, which is then perforated with a pinking wheel or picker, care being taken to follow every line of the pattern. The perforated sheet is then securely fastened to the surface to be decorated, when the designs are transferred by means of a pouncing bag, light or dark colored powders (gilder's whiting, dry umber or charcoal) being used, according as the surface is dark or light. The colors or gilding then follow. After this work is done the body goes to the varnish room where two coats, one of rubbing one of finishing varnish, are applied, the first being carefully rubbed down; all of which can be done in about sixteen days after the car reaches the paint shop.

When the time is not limited the following formula and practice may be followed for a first class job: The priming coat may consist of keg lead with pure raw oil mixed to about the consistency of milk; this being well brushed into the pores, screw and nail holes, is left to dry three or four days, when it is sandpapered lightly. The first coat, consisting of keg lead mixed with raw oil two parts, japan one part, with enough turpentine to make it work easily, is next laid on, and after two days the holes are carefully filled with putty which is made of dry white lead mixed with equal parts of japan and rubbing varnish. After the putty is dry the surface is again sandpapered. The body is now ready for the second coat which may consist of one part keg lead, two parts raw oil mixed thick with japan and then thinned with turpentine. The rough places are now filled with soft putty, and after this becomes dry it is smoothed off and the surface is ready for the next coat which consists of keg lead mixed thick with turpentine, to which is added a little oil, japan and rubbing varnish to bind the coat well. After drying, three or four coats or enough to fill the work are next laid on. These coats consist of English filling three parts (light for light grounds, and dark for dark grounds) dry white lead two parts, keg lead one part, mixed with japan two parts, rubbing varnish one part, and turpentine to thin properly. This being rubbed down and cleaned, the colors are applied until the surfaces are properly covered. Rubbing varnish is next applied and being thoroughly rubbed down with pumice stone, the lettering and ornamentation may follow, and this is usually done by another class of workmen. After being rubbed down well, finishing varnish is applied. If each coat has dried properly, paint applied in this manner will last for years without cracking, peeling or fading. To produce the smooth, ivory-like finish which some fine cars present, it sometimes requires as many as fifteen coats of paint and varnish. The outside decoration should be solid, plain and neat; too many large scrolls sometimes spoil the beauty of a car.

The inside finish is now put on by another class of workmen, and in some respects this is the most particular work on the car. The ornamentation may be plain or rich as the taste may demand. The headings are often finished in hand painted designs, including landscapes, figures of men and animals, wreaths of autumn leaves, spring flowers and vines, or they may be ornamented with stencil work or covered with stucco. The woodwork is sometimes finished dull and sometimes in bright colors. If dull finish is wanted, the surface should be flattened. All woodwork after filling may be treated with rubbing varnish.

The above methods are subject to modifications depending upon conditions. For instance: For work that is to be put in service near the sea shore where the air is keen and salty, plenty of raw oil should be used in mixing the paints, while japan should be avoided, but in case a little must be used to hasten the drying, it should be mixed with gold size and spar varnish. The same is true for cold climates, in which case the primary coat may be pure raw oil.

Both hard and soft putty are employed in car building; the former is made by mixing, say, five pounds of dry white lead with japan and rubbing varnish half and half, to which is added a little turpentine and a small quantity (half an ounce) of keg lead. Soft putty is made of dry white lead and gilder's

whiting, half and half, mixed with keg lead one-third, thinned with boiled oil, and about one gill of light brown varnish to five pounds of putty. Before paint is applied to panels or sills all sap portions should receive a coat of white shellac. In case sills are season checked the checks should first be filled with a paste made of fine sawdust and glue and left to dry before painting. Before applying paint to old cars, such portions as have become covered with oil or grease should be carefully cleaned and covered with a coat of shellac.

Rough stuff or filling-coat may be purchased from dealers ready prepared for use, or may be made in the shop as follows:

For dark filling mix common yellow ochre with brown japan (one-half) and rubbing varnish (one-fourth), thin with turpentine. For white work, mix thoroughly ten pounds of dry, white lead, two pounds of ground pumice stone No. 1½, one quart of rubbing varnish, one quart of light brown japan varnish, two pounds of keg lead. Transparent colors should be handled quickly, and laps on large panels should be avoided. Lay off vertically and keep a cool edge (as the painters express it).

Before applying the varnish the surface should be carefully washed, special attention being given to remove the pumice stone from corners and crevices, otherwise the work will be full of specks and look dirty. Fine rubbing powder, not coarser than No. 1 or ½ should be employed for treating the rubbing varnish coats, and the more time taken for this process the more satisfactory the job. Head linings, after being carfully sandpapered and cleaned, are treated first to a coat of filling, which may be made made of corn starch mixed as directed for soft putty. After this begins to stiffen and turn white rub thoroughly against the grain with a bunch of Excelsior. When this is thoroughly dry apply one or two coats of shellac. If two are put on sandpaper the first carefully, then add rubbing varnish one or two coats, and follow with the ornamenting. After the ornamenting and striping is finished add one or two coats of varnish.

To flat varnish rub with a piece of thick felt and ground pumice stone, then wash thoroughly, using a soft sponge and plenty of water, and dry off with a piece of chamois.

To prepare old cars for repainting, if the paint is not badly cracked, rub the lettering and ornamenting to a close surface with rubbing brick, then apply a preparatory coat, and when dry putty up dents and scratches. After three or four hours, put on with a broad knife a plaster putty coat, and when this has hardened, sandpaper. In case the paint is cracked it will be necessary to burn it off, which can be done with a Wellington lamp, using benzine for fuel (Fig. 437.) Begin on the right, so as to back away from the flame, and scrape off the paint with a broad knife or with a putty knife. After burning, sandpaper well and prime with keg lead, and plaster as before.

It sometimes happens that the panels or sides of a highly finished and handsomely decorated car become broken or defaced soon after being put in service, in which case it requires great skill to repair and repaint so that the new work will correspond with the original designs. These may be copied, however, in the following manner:

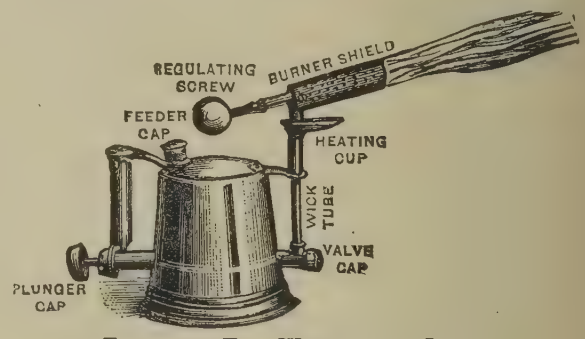


FIG. 437.—THE WELLINGTON LAMP.

Trace over the outlines of the uninjured designs with a paint made of lamp black, raw oil and a little turpentine, using a fine camel hair pencil. Lay over this a sheet of heavy drawing paper, carefully fitted, and hold in place and rub over the entire surface evenly with the flat of the hand. The sheet, on being removed, will have an exact copy of the design, when it may be secured to a flat board, and perforated as described above for original designs. Place this sheet over the new surface and pounce the same as for new work, when a duplicate copy of the original will be transferred to the

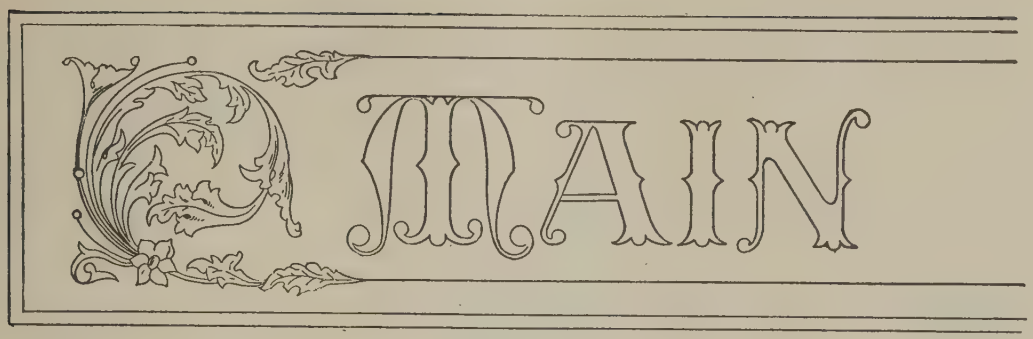


FIG. 438.

Striping and lettering in gold. Ornaments shaded with asphaltum. Striping and lettering edged.

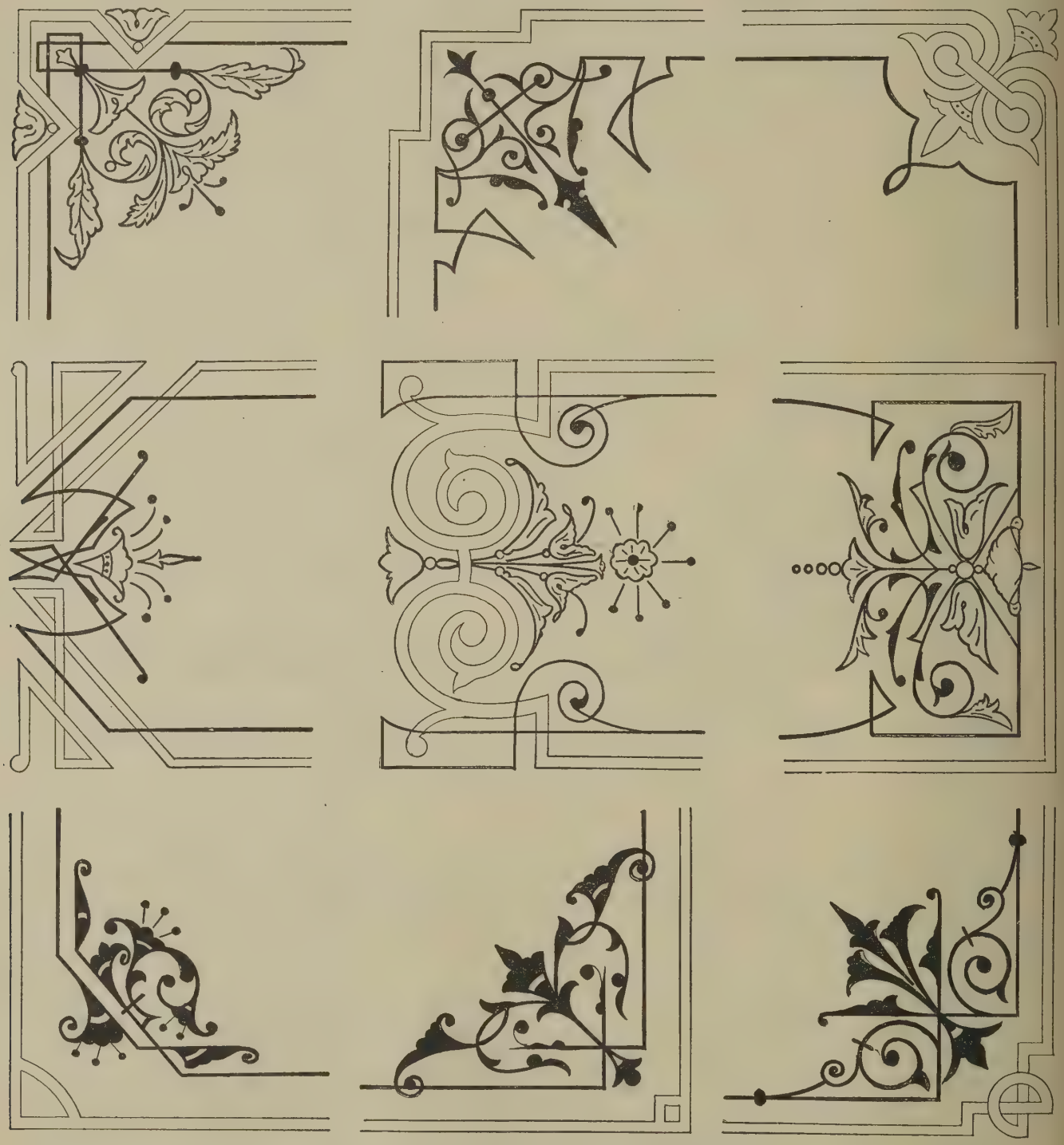
FIG. 439.

Ornaments gold. Striping same. Lettering nickel edged and cast shadow. Natural tint for ground work on panel. Ornaments shaded or edged, or both, as desired.

FIG. 440.—ORNAMENTAL DESIGNS AND LETTERING FOR HALF MAIN PANEL.

Ornaments gold, edged with neutral tint. Letters and broad line nickel edged. Fine line gold. Rosettes gold shaded and edged.

new work. Remove the perforated sheet, fasten it again to a flat board, and with colored crayons copy the shades of the originals. This being put in a convenient position, will save time and aid the painter to produce an exact copy.



Fig, 441.—Designs for Main Panel Ornaments.

The appearance of a finished car will depend largely upon the skill and taste that have been exercised by the head painter in making the designs for letters and ornamentation, and in so blending the finishing colors that they will harmonize. Care must also be exercised in selecting the colors, that, when faded even, some degree of harmony will be preserved.

In the direction of outside ornamentation and lettering there is a broad field in which a painter can

exercise his ingenuity. No set designs for copying can be given, which will be suitable in all cases, but a few are presented in this connection which may suggest to the thoughtful painter other conventional forms which he can introduce with pleasing effect (Fig. 438).

The seats may be upholstered with hair or rattan cushions, or seats and backs may be made of perforated veneer covered with Wilton carpet. In some cases builders have seat carpeting woven in special designs. If window curtains are employed, they should be of durable material (Russia leather) and mounted on self acting stop rollers with brass guide rods. In some climates, neither curtains, cushions nor carpeting can be employed, owing to their furnishing a harbor for insects.

The floor may be covered with matting made of wood, wire or jute. A very durable floor finish, known as the Everett system, consists in reinforcing the plank with narrow wooden strips, about half an inch apart, laid lengthwise in closed cars, and crosswise in open cars and fastened with screws. To prevent warping, the strips should be divided into sections of three or four feet. In some cases the floors are first covered with linoleum before the strips are put down.

The bronze trimmings are next put on, and include the end window guard rods, window lifts, strap pole brackets, bell bushings and bells, fare wickets, brake handles, etc.

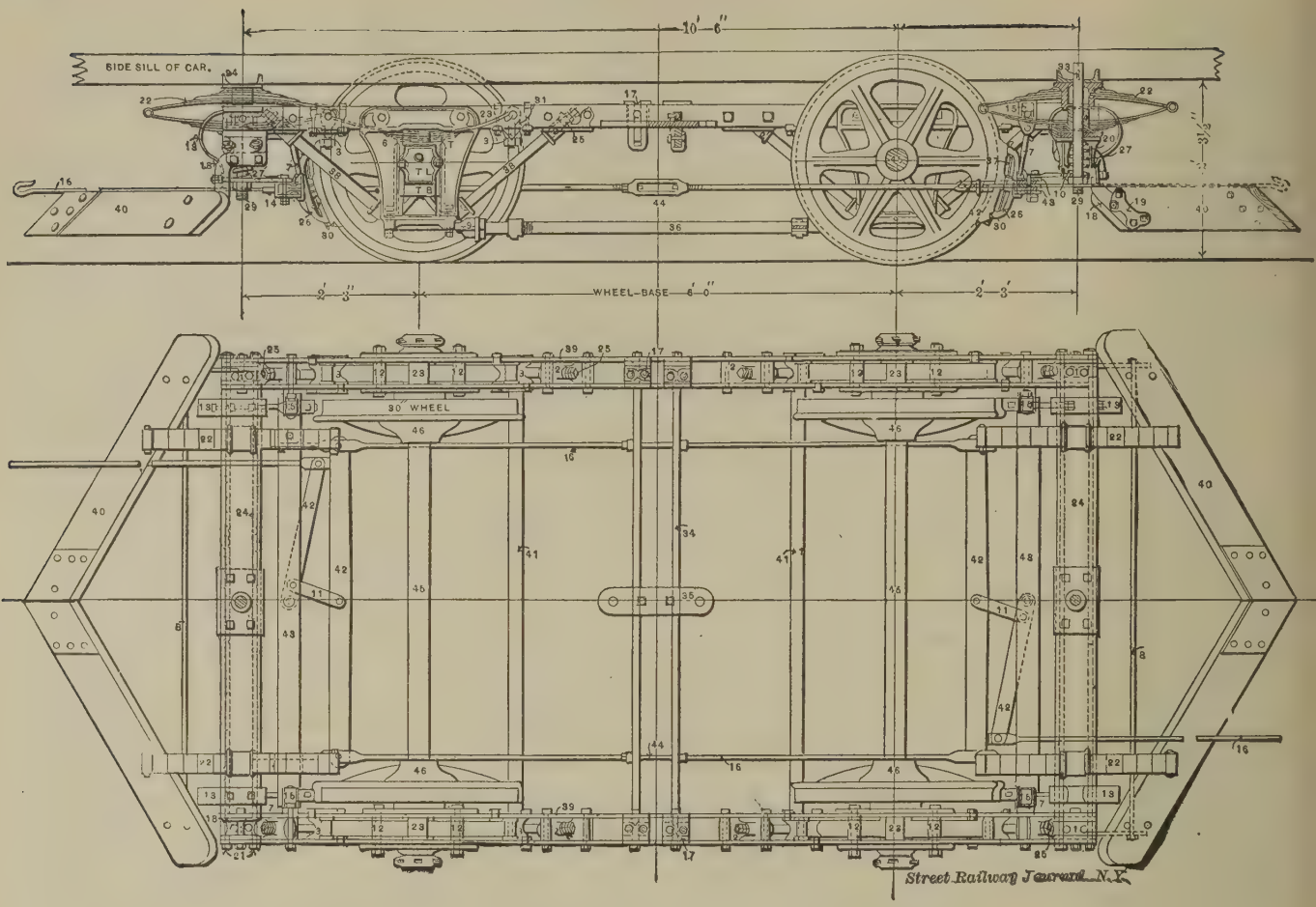
The body being sufficiently elevated the truck is run under, body lowered and sills attached to the truck. The spring box, radiating draw bar, and carriers are now added, all wires are connected, the trolley stand is put in place, when the car is run out and is ready for the road or for shipping.

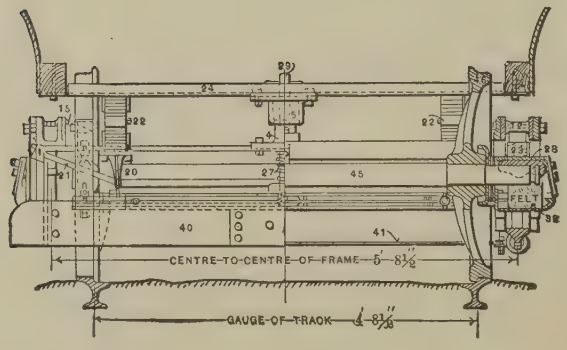
CAR TRUCKS.

The advent of mechanical traction has necessitated the employment of an independent truck for supporting the motors, which would relieve the body from the weight and strain, and permit of its being readily removed.

Truck building is made a business by itself, and it is not necessarily carried on where the coaches are made, although most car shops have a truck department, and make some special type of truck. Trucks are made in a great variety, adapted to the various forms of motors and power employed, and purchasers of street cars usually specify the style and make of truck upon which they wish their cars to be mounted.

Trucks are not only modelled to suit the different types of motors employed, but also for use under long and short cars employing the same motors, while in the material used and in the method of construction we find a wide range of practice. This is not surprising, for in horse car practice we still find many forms of running gear, with no approach to a universal standard, except it be in the matter of a journal box, which, fortunately, is admirably adapted for use with mechanically propelled cars. But the running gear of a four wheel horse or trail car cannot be regarded as a truck in the sense in which the term is applied to the combined appliances upon which the bodies of mechanically propelled cars are mounted. Hence, the self contained motor truck is of comparatively recent origin, and may be said to have had its birth with the advent of electric traction. It is true that rigid frames have been employed in the construction of trucks for steam and gas motors and for grip cars, but nothing growing out of the experience had with these trucks, nor, indeed, from steam railway practice, serves as a guide in the construction of electric trucks so that they will meet the peculiar conditions under which electric railways are constructed and operated. Hence, it is not surprising that radical defects have heretofore entered into truck construction, attended with damaging and fatal results to motor, car body and track, as the scrap heap of many a street railway can testify. The cause of failure in some cases and of success in others is owing, no doubt, to the methods followed by the inventors. One class invented a theory, and then denied or ignored facts which demonstrated its fallacy, while the other class ascertained and studied the facts and worked along the line of scientific truth evolved from the plain teachings of experience. While gratifying success has crowned the labors of the latter class,





LIST OF PARTS OF THE TAYLOR TRUCK.

1. Corner casting.
2. Inside socket casting.
3. Half elliptic spring plate.
4. Body bearing on truck.
5. Body bearing on body.
6. Pedestal.
7. Brake hanger.
8. Pilot tie rod.
9. Bottom stay casting.
10. End coil spring plate.
11. Brake beam clevis.
12. Pedestal thimble.
13. Brake release spring.
14. Brake beam and clevis guide.
15. Brake hanger casting.
16. Brake rod.
17. Motor hanger casting.
18. Pilot hanger.
19. Pilot hanger casting.
20. End truss rod chair.
21. End truss rod.
22. Elliptic spring.
23. Half elliptic spring.
24. End channel.
25. Adjustment bolt.
26. Brake head.

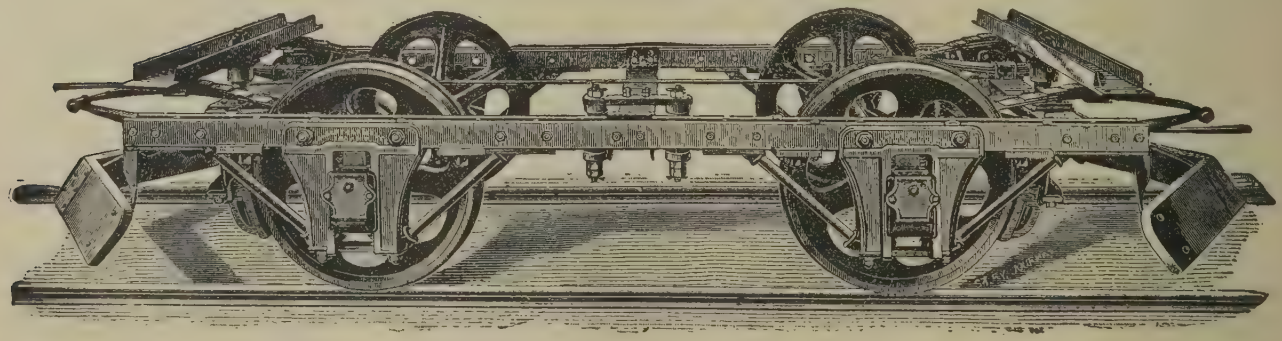


FIG. 442.—TAYLOR TRUCK—GILBERT CAR MANUFACTURING CO.

27. End coil spring.
28. Journal brass.
29. King bolt.
30. Brake shoe.
31. Spring clevis.
32. Journal box packing.
33. King bolt key.
34. Cross bar.
35. Motor hanger.
36. Bottom stay.
37. Brake head key.
38. Pedestal brace.
39. Side frame.
40. Pilot.
41. Cross stay.
42. Brake lever.
43. Brake beam.
44. Brake adjustment.
45. Axle.
46. Wheel.
T. B. Journal box.
T. L. Journal box lid.

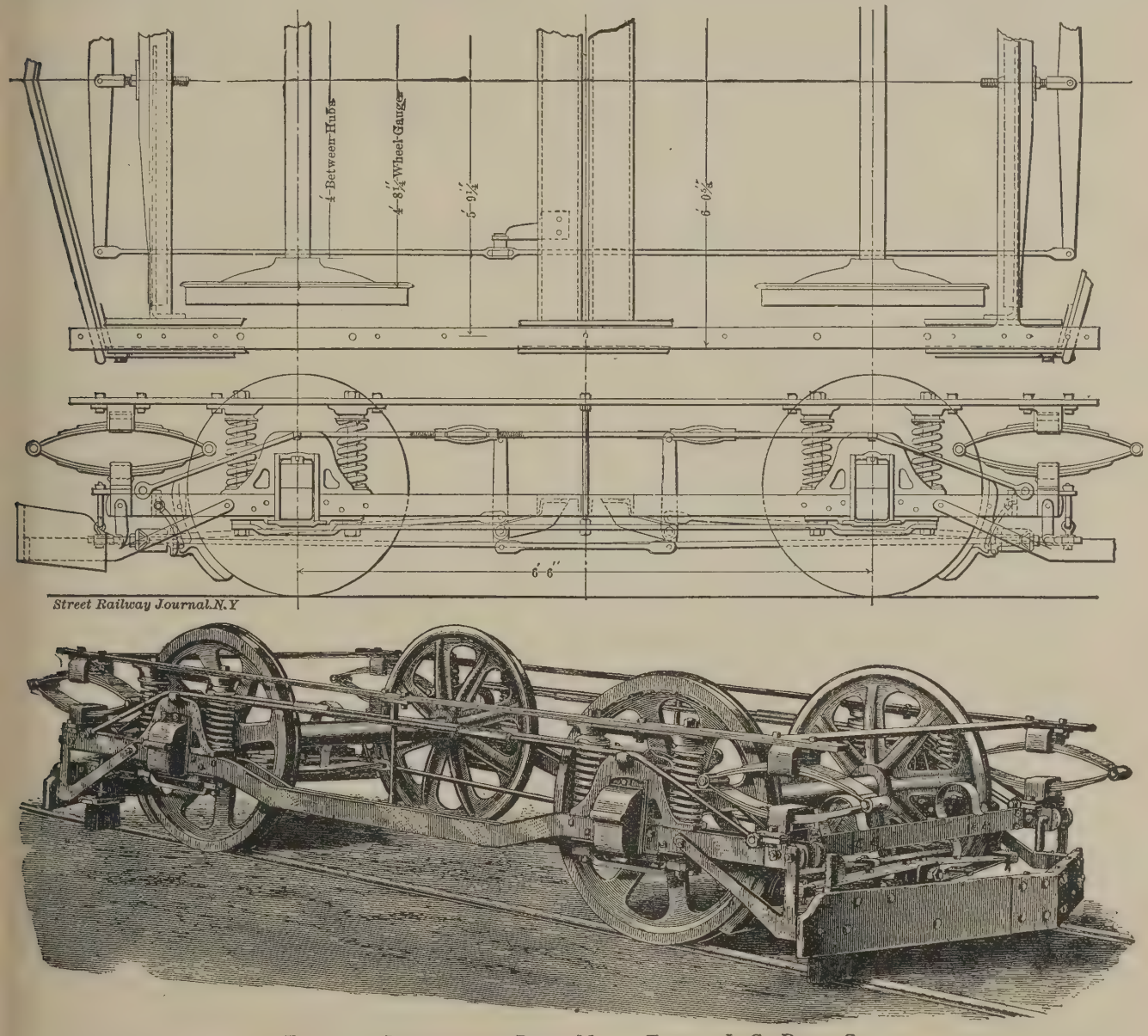


FIG. 443.—INDEPENDENT RIGID MOTOR TRUCK—J. G. BRILL CO.

so that the market is well supplied with a great many models and designs that are used and accepted as the best attainable under the circumstances, no one claims that a standard truck has yet been devised, one that will give satisfactory results and serve as a cure-all for the many minor evils in which the service abounds. The possibilities of making trucks better or worse are almost as wide as the range of human effort, for which reason it may not be idle to study the lessons that may be drawn from the logic of events and actual practice, with the hope of a nearer approach to a satisfactory standard. By reference to the accompanying illustrations (Figs. 442 to 459), it will be observed that an immense amount of mechanical genius has already been devoted to improvements in truck construction, and that important changes are still being made.

Trucks are the fundamental features of an electric car, and the details include many parts, some of the most important of which are wheels, axles, journal boxes, journal bearings, motor bearings, frame, springs, guards and brake appliances. The importance of the car truck arises from the fact that it combines these parts with the motor, gears and a large number of auxiliary appliances under such conditions that the aggregate combination forms, in a mechanical sense, a car; for that which is above the truck is only the car body. There are four wheel trucks and six wheel trucks employed in electric traction, the latter being of a radial type. and chiefly employed under exceptionally long cars (Fig. 452). A large number of eight wheel cars are also employed, and with these the wheels and other necessary appliances are combined in two sets of four wheel trucks, each of which helps to support the car body (Figs. 453 to 455). The primary object of this arrangement, and of the six wheel trucks, is to enable long car bodies to be conveniently moved around sharp curves. Various other purposes are to be served in the construction of an electric truck, each of which must be considered in attempting to improve the details of construction, and to promote the ends of electric traction.

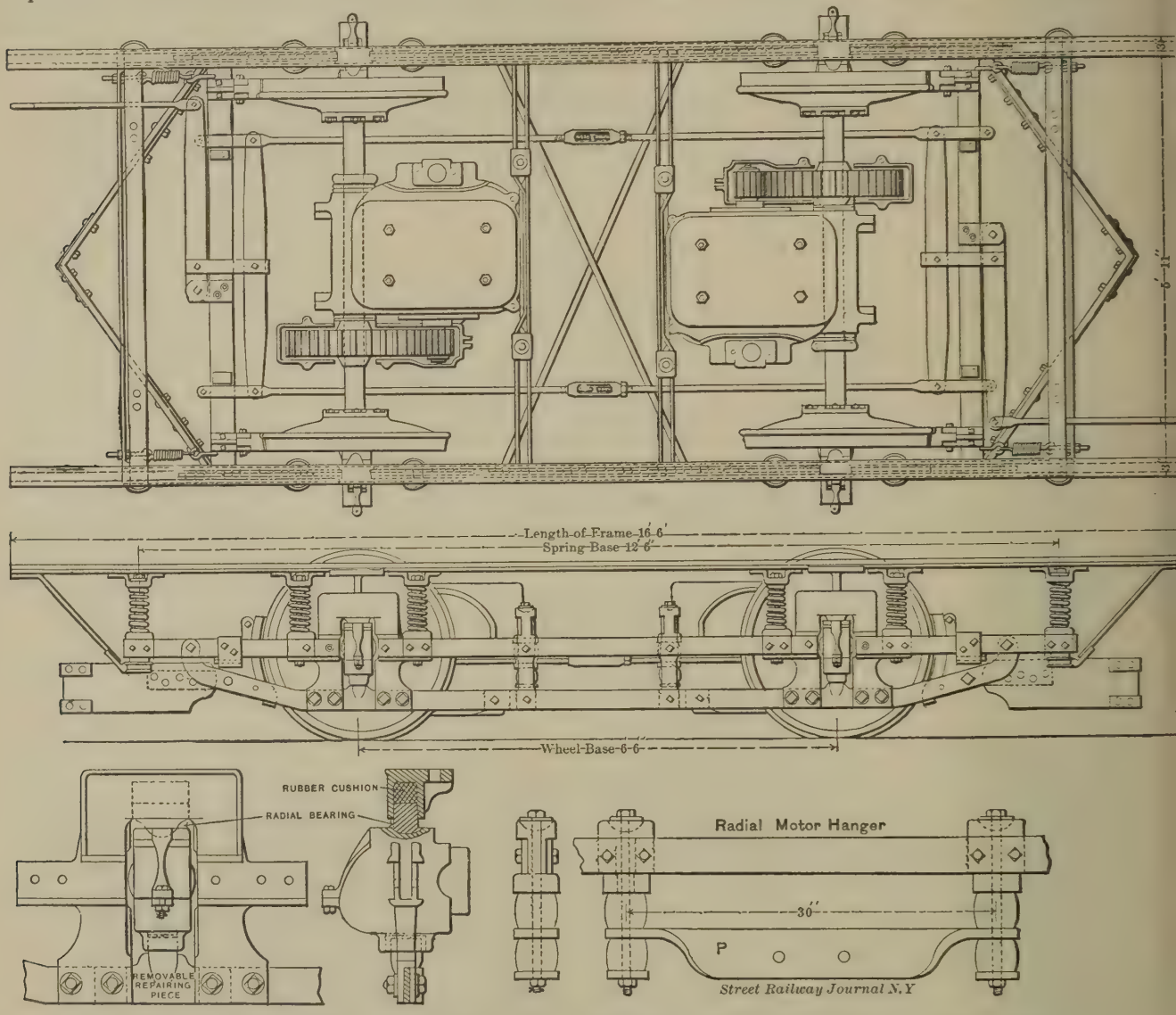


FIG. 444.—PECKHAM'S FLEXIBLE NON-OSCILLATING MOTOR TRUCK WITH RADIAL JOURNAL BOX.

The mutual relations of truck and track are an important consideration, for no amount of skill or material expended in the building of a truck will

produce a structure that will give prolonged service upon an uneven and badly constructed track.

The essential features of an electric motor truck are strength and durability without too great weight. It should be so framed and braced at all points, as to prevent its getting out of square, and should not depend at all upon the car body, but should rather reinforce the body framing and prevent the racking of joints. It would seem to be as simple a matter to design a frame that would support the motors and maintain the gears in proper relation, as to set up any machine in which gears are employed, but service develops many difficulties that must be met. The motor must be properly insulated, and one end must be flexibly supported to relieve the gears from sudden strains at starting, and to relieve as much as possible the shocks due to its own weight. While these points cannot be ignored, the design must be such as to allow of ready access to the different parts of the motor, and to allow of the armature and wheels being readily removed. The brake mechanism must be provided for, both to insure reliable action and to admit of adjustment and repairs, and, as far as possible, so mounted as not to be subject to the spring motion of the car. Provision must be made for attaching the car body in such a manner that it may be readily removed ; while if a long body is to be mounted upon a truck with a short wheel base, provision must be made by extending the spring base and providing it with auxiliary graduated springs to prevent side and end oscillation, both with light and heavy loads (Figs. 443 and 444). The latter requirement is quite important, not only on account of the comfort of the passengers, but because of the destructive effect of the oscillation upon the wiring and the car body, and because it reduces the tractive effort of the wheels and affects the life of the wheels. This point has been generally overlooked, but a case is cited where trucks of different types are employed on the same line, both being equipped with wheels of the same make and operated under the same conditions, but on the one in which oscillation is prevented and the weight equally distributed the wheels have a longer life ; and the car operates on a slippery track and through snow with much better results than the one lacking these provisions.

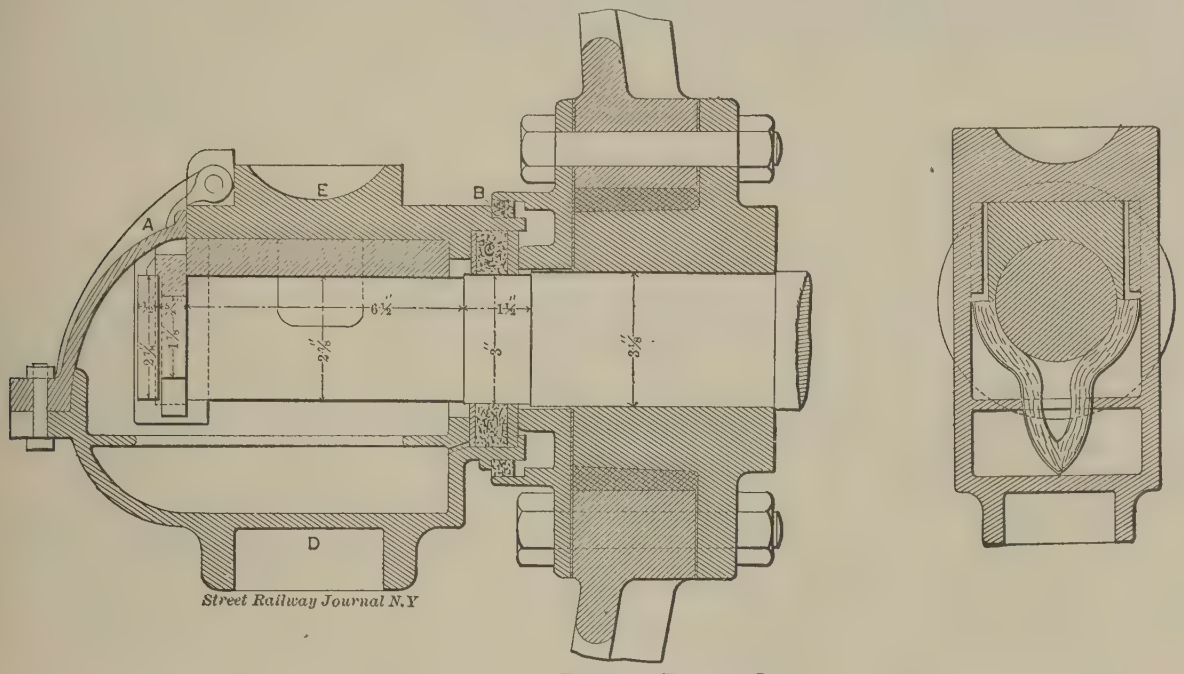


FIG. 444A.—JOURNAL BOX FOR RADIAL GEAR.

In case double trucks are employed, which carry only one motor, it is desirable to so pivot the truck that the driving wheels will carry a large portion of the weight in order to secure the maximum

amount of traction. In connection with such an arrangement the idle wheels are made smaller than the drivers so that the truck will swivel without interfering with the steps or the car framing, permitting of the body being mounted several inches lower than where the wheels are all of the same diameter. The use of the "waterproof" and other motors having the upper half hinged, make it necessary to dispense with bolster and pivot and leave the truck entirely open in the centre, so that access may be had to them for repairs and inspection through the trap doors of the floor. Hence, side bearings must be provided, which shall correspond to arcs having their pivotal points at the centre (Fig. 453). Other types of motor trucks are illustrated in the first chapter.

Two types of cable trucks are illustrated in Figs. 456 and 457. The axles of the first are provided with drums, on which the brake shoes act. This arrangement prevents the brake wear on the car wheels, and being usually dry and free from mud, they offer a better braking surface than the car wheel, and admit of the employment of a wooden brake shoe.

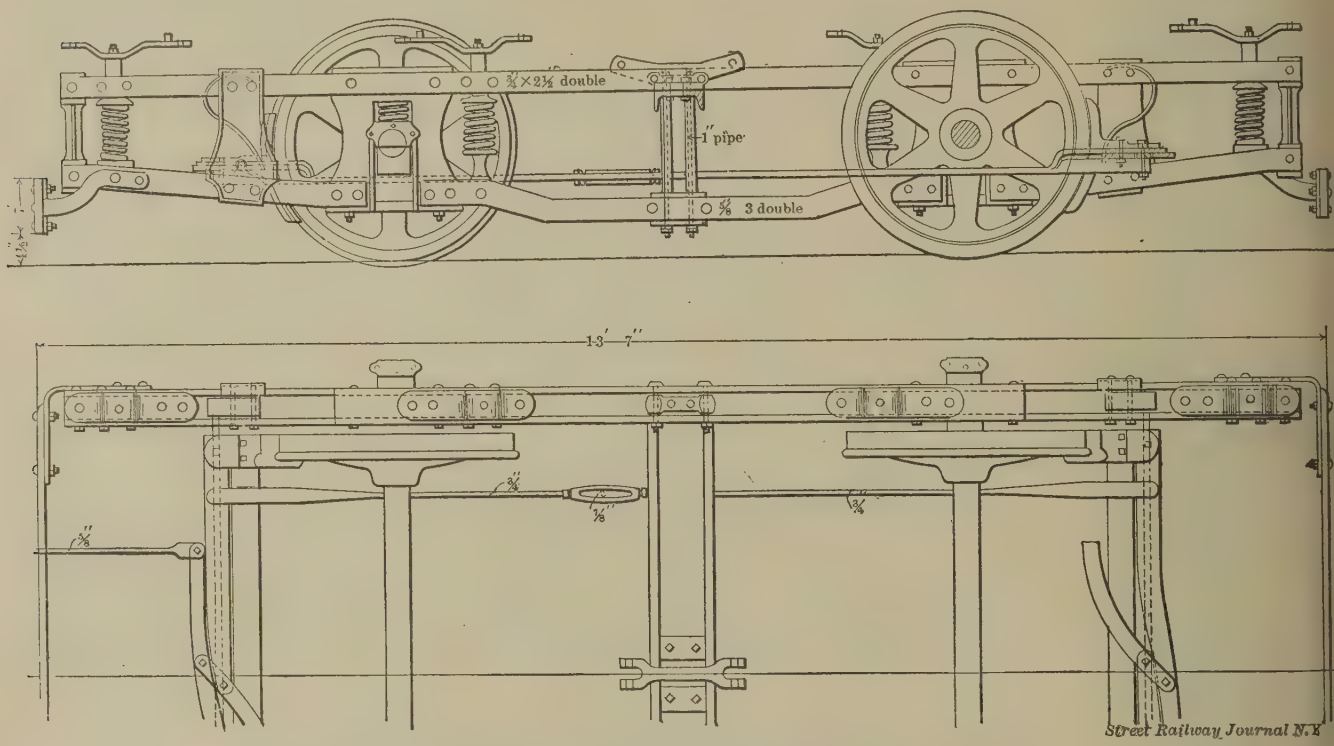


FIG. 445.—MANIER TRUCK—LEWIS & FOWLER MANUFACTURING CO.

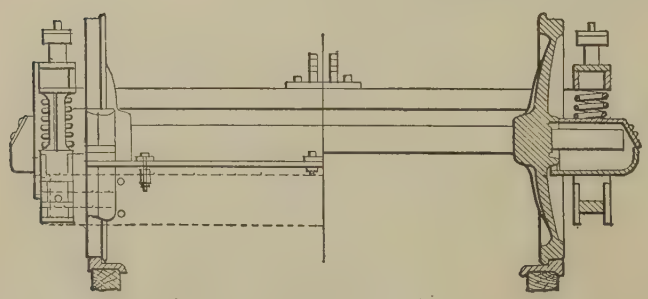


FIG. 445A.—MANIER TRUCK.

In the manufacture and repair of car trucks, the requirements, as we have seen, are very exacting and include a number of parts which must be specially manufactured for their construction. Among the auxiliary industries which perform important service in this direction, are those which manufacture wheels, axles and springs, and, although this work is usually conducted in independent establishments, it is important that some general knowledge of the characteristics of these parts and details of manufacture be had to serve as a guide in their selection and prevent disastrous mistakes, for the fortunes of a company may be made or marred by success or failure in the selection of these three items alone.

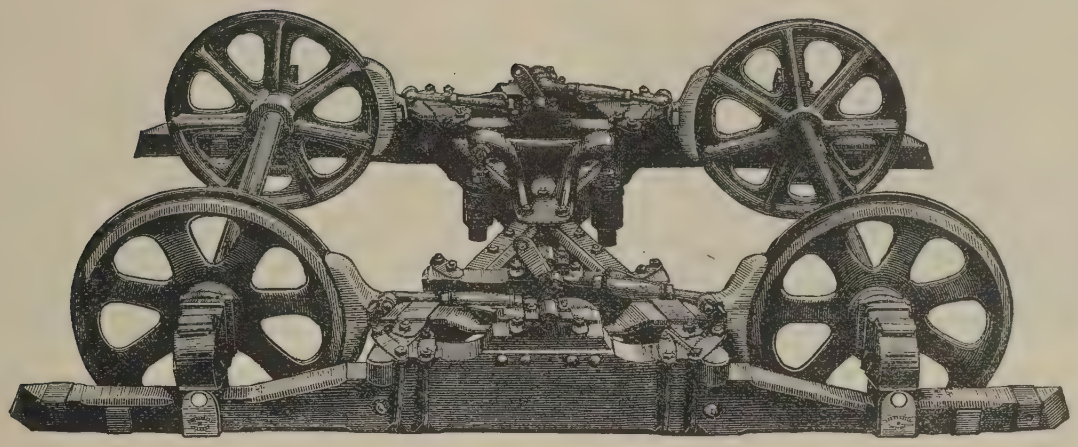


FIG. 446.—STEPHENSON'S MOTOR TRUCK.

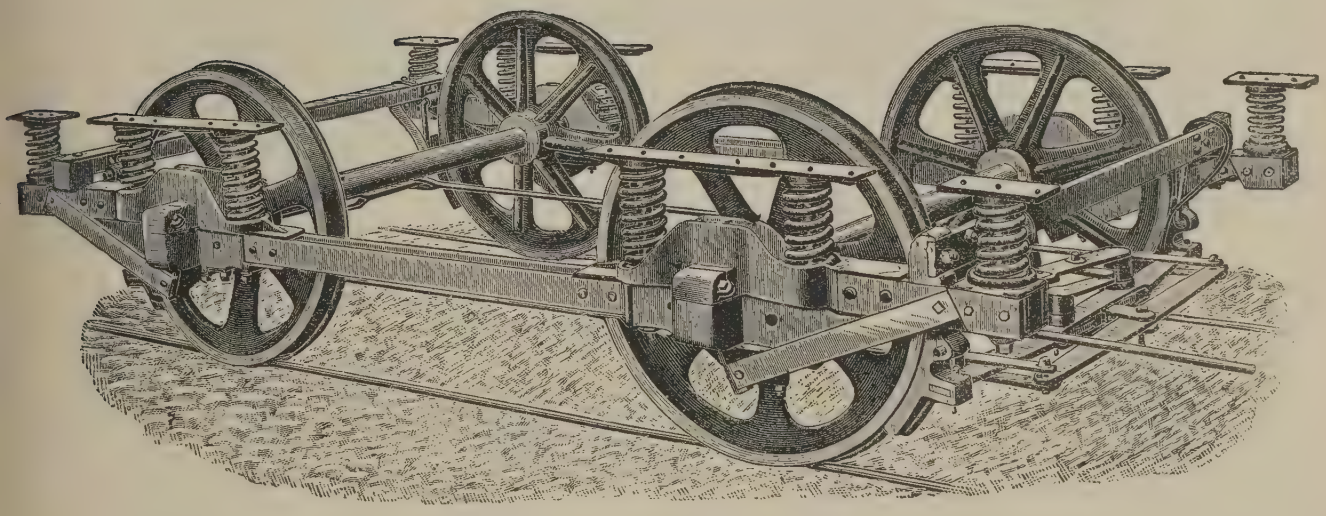


FIG. 447.—DORNER & DUTTON'S IMPROVED MOTOR TRUCK.

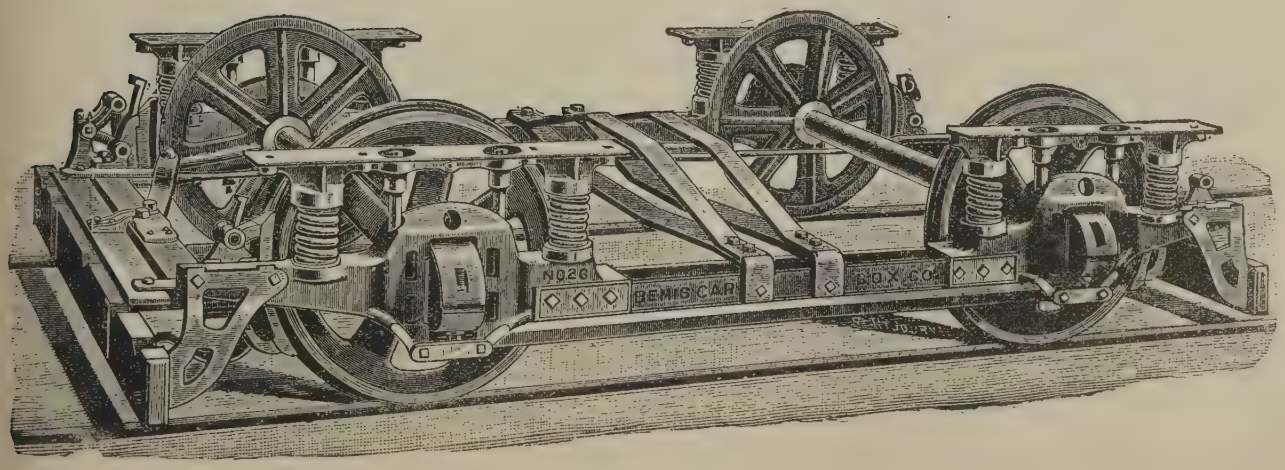


FIG. 448.—BEMIS CAR BOX CO.'S NEW ELECTRIC TRUCK.

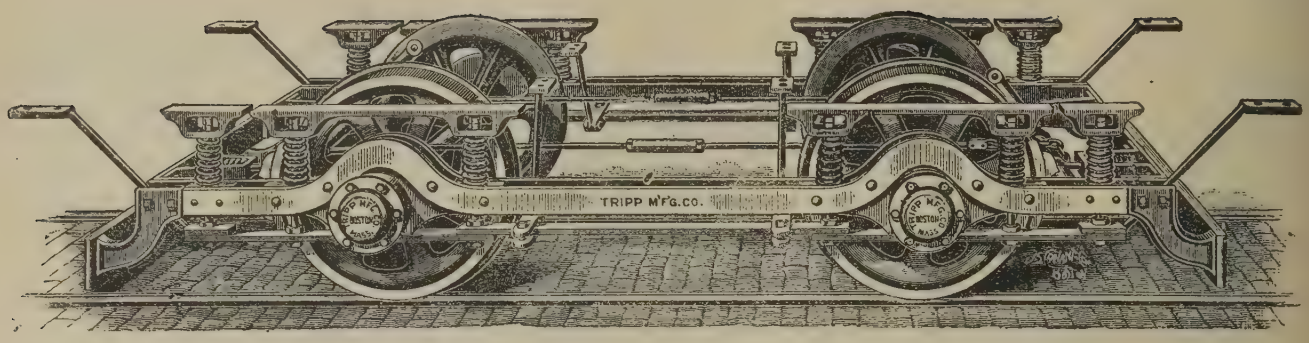


FIG. 449.—TRIPP ELECTRIC TRUCK WITH ROLLER BEARINGS.

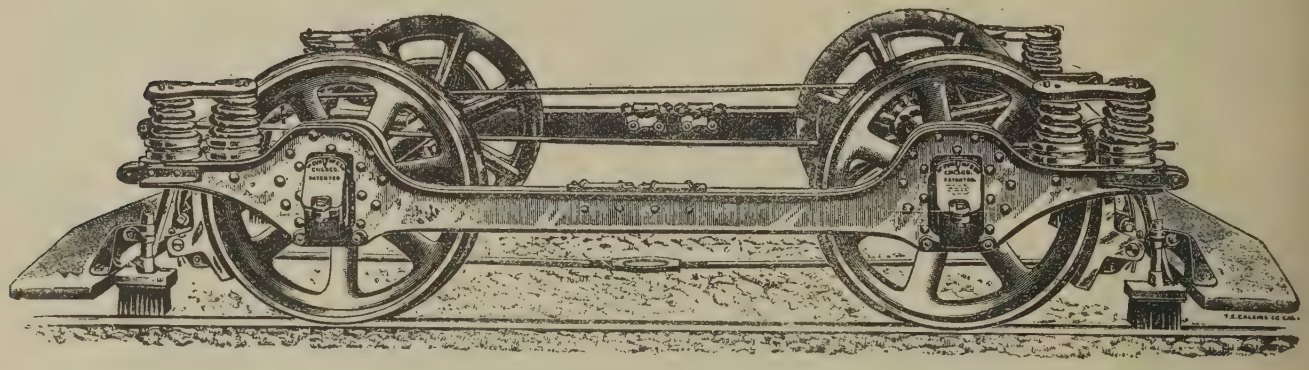


FIG. 450.—MCGUIRE TRUCK.

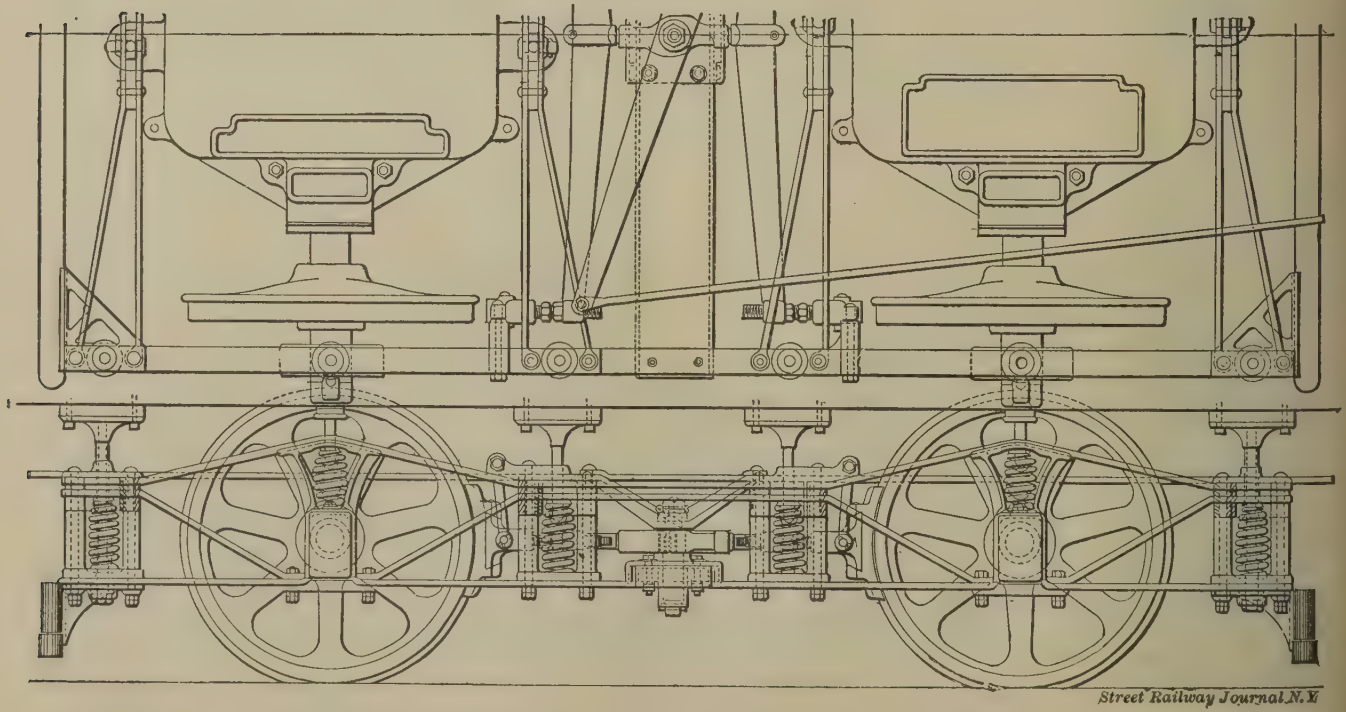


FIG. 451.—ELECTRIC TRUCK, WESTINGHOUSE MOTORS—BALTIMORE CAR WHEEL CO.

WHEELS.

Chilled cast iron wheels constitute the principal portion of all wheels manufactured for street railway service, but the manufacture of the various types of steel and steel tired wheels for motor cars is a growing industry, and the demand for them arises chiefly from the belief that they are capable of performing a greater amount of service, have a greater tractive force, and are safer under high speed electric cars. In regard to the relative economy, it is claimed for steel tired wheels that the extra amount of service which they are usually capable of performing, and consequent diminution of the number of changes of wheels, compensate for the difference in first cost. This theory is ably advocated on the one hand, and forcibly opposed on

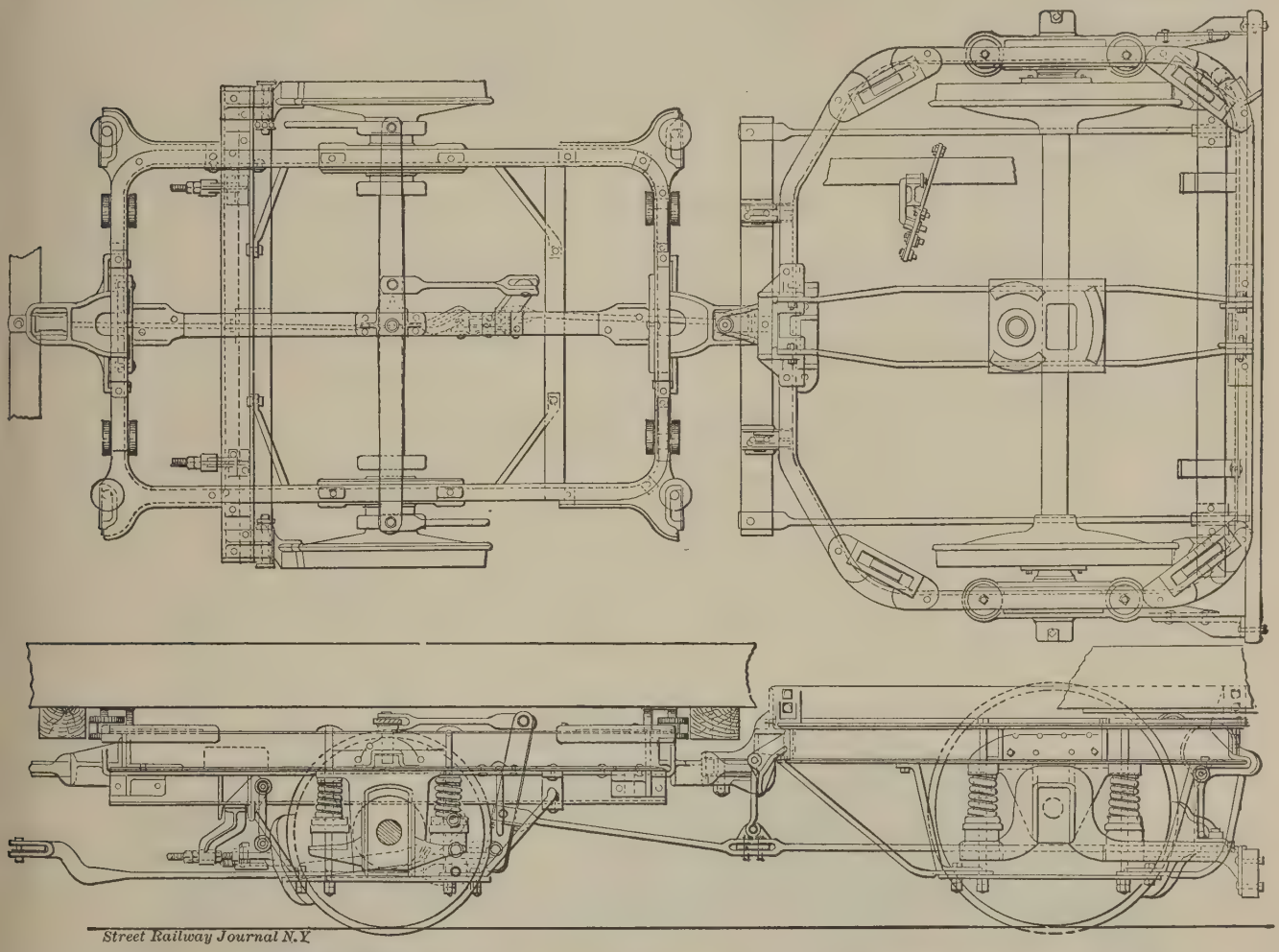
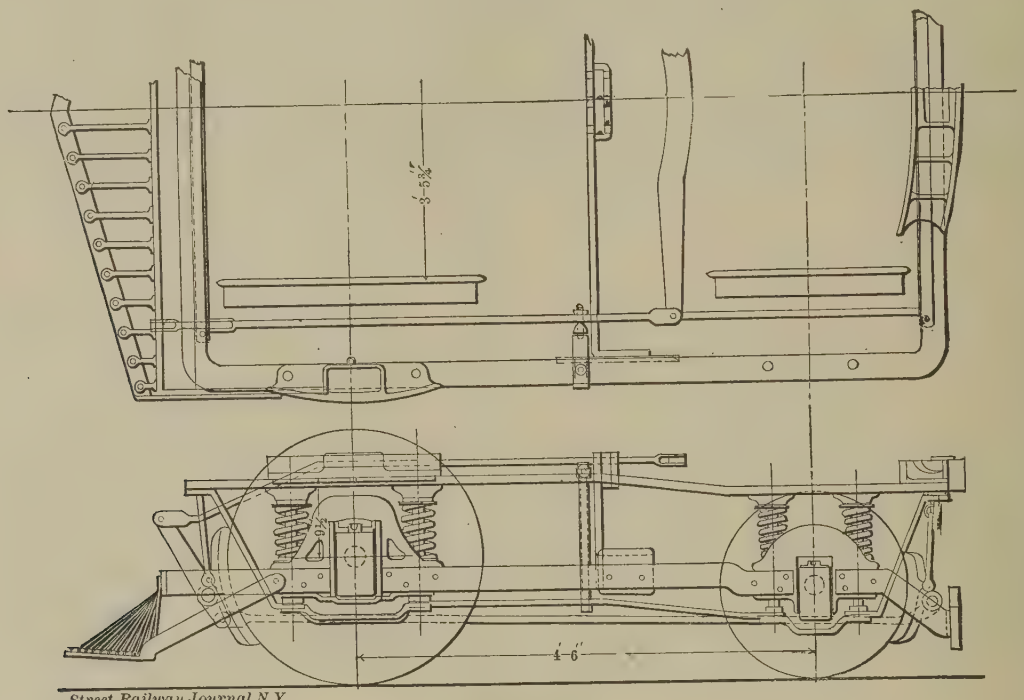


FIG. 452.—ROBINSON RADIAL TRUCK.

the other, by manufacturers of chilled wheels and some street railway managers. In order to determine the relative value of each type of wheel under particular conditions, it will be necessary to make a trial of different wheels, and carefully watch their performance. It must not be concluded, however, that a poor result with one make of wheel proves that all others of the same kind are defective.

There are records of the performances of both types of wheels, made by reputable manufacturers, that are very creditable, and in some cases, under favorable circumstances, a degree of excellence has been attained that has fully met, or even exceeded, all reasonable expectations, but unsatisfactory results have been reported in both cases where wheels were furnished at a price too low to afford compensation for the skill, care and labor necessary in the manufacture of a first class article. In making a choice between cast and steel tired wheels, one must be governed somewhat by the reputation of



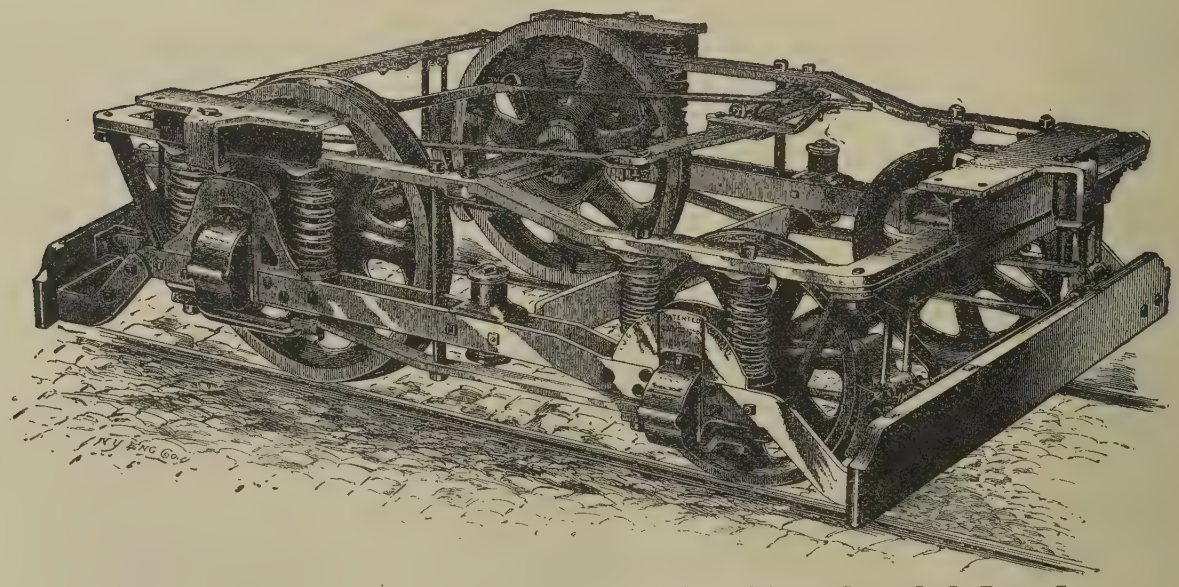


FIG. 453.—MAXIMUM TRACTION PIVOTAL TRUCK FOR EIGHT WHEEL CARS—J. G. BRILL CO.

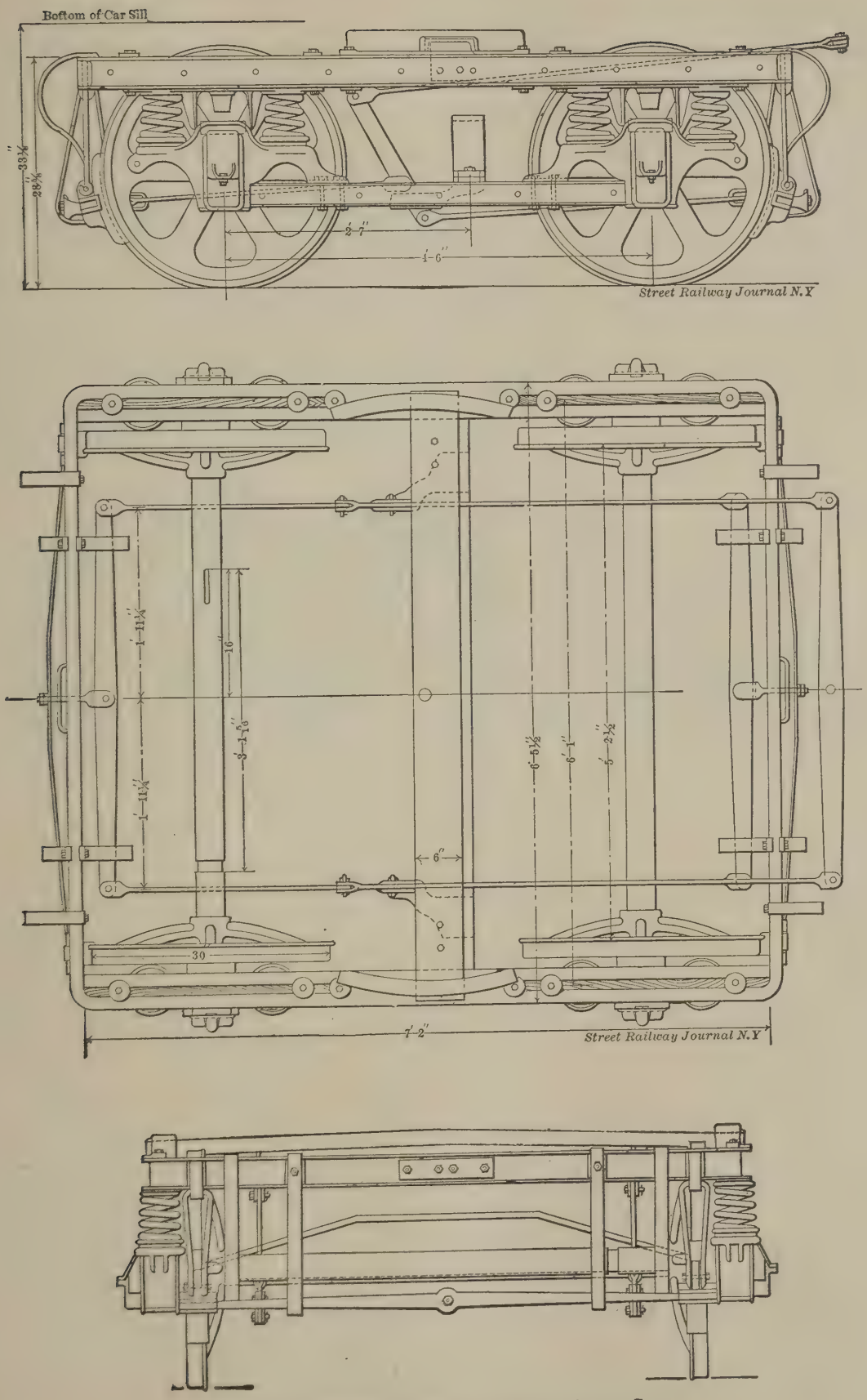


FIG. 454.—McGUIRE TRUCK FOR EIGHT WHEEL CARS.

the makers, and by the peculiar conditions existing on the line where the wheels are to be put in service. For instance: If the conditions are such that the flange of the wheel will be worn out before the tread needs turning down, it will not be economical to employ steel tired wheels.

The manufacture of chilled car wheels depends upon the principle that when certain kinds of cast iron are melted and poured against a metallic mould or "chill," that portion of the iron next to the mould is suddenly cooled and becomes white and crystalline, while it is inseparably united to the inner portion which remains gray and more

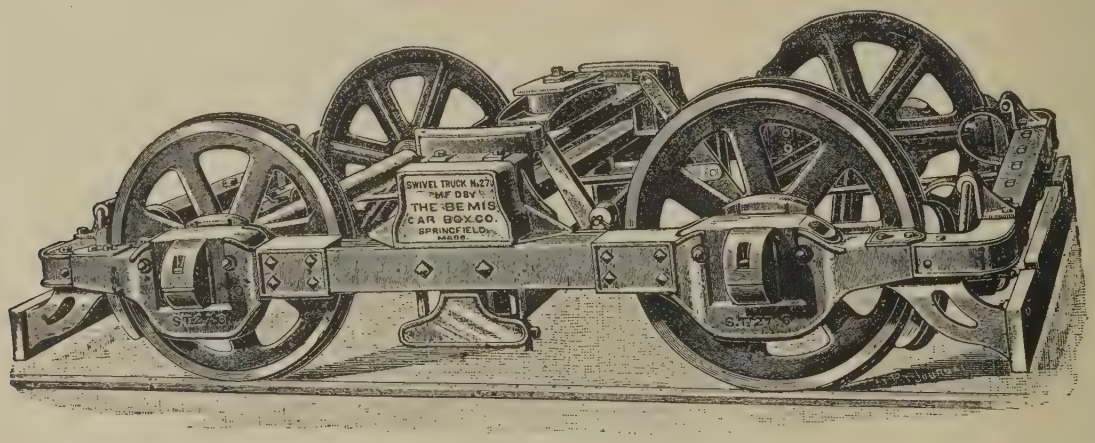


FIG. 455.—TRUCK FOR EIGHT WHEEL CARS, DESIGNED FOR ONE OR TWO MOTORS—BEMIS CAR BOX CO.

or less tough and fibrous (Fig. 461). Hence, by placing in the mould a metal ring having the form of the tread and flange, the molten metal surges against it as it is poured, causing the wearing parts of the wheel to become hard and very durable.

Formerly the "chill" consisted exclusively of an ordinary iron ring, but in order to take advantage of the laws of expansion and contraction, the "contracting chill" has been devised, which, in some form, is now to a considerable extent used. In this type of chill the inner surface is divided into segments by means of slots so small that the iron does not penetrate therein to any extent. As the metal is poured the segments become heated and expand inwardly, keeping the inner surface in contact with the metal.

In order to increase the depth of the chilled surface and make it uniform, some manufacturers employ a "chill" in which the expansion and contraction are controlled by external means. One of the most popular chills of this type is cast with a hollow outer rim, having its inner face or chilling surface divided radially into inch sections by a saw cut, but further back by a wider opening to secure ventilation. The application is about as follows: The mould being prepared, live steam is passed through the outer hollow rim of the chill for a brief period, causing it to expand and carrying with it the chill segments, thus increasing slightly the diameter of the chilling surface. As soon as the pouring begins, the steam is shut off and cold water is admitted to the chamber of the chill, causing the rim to contract, thus holding the inner surface in contact with the metal as it shrinks in cooling. Another advantage claimed for this process is that the metal can be poured rapidly and while very hot, giving a more solid and uniformly round casting than with slow pouring.

On the other hand, many wheel makers continue the use of the solid chill, claiming that, with proper care, the metal can be poured as rapidly and as hot as with the contracting chill, and since the latter is liable to get out of order, no special benefit is obtained by its use.

The question regarding quality, depth of chill, rotundity and strength, is one that the purchaser must decide by subjecting samples to suitable tests, some of which are suggested later on. The methods of manufacture and the use of different types of

chill is an affair of the makers; the consumer is interested only in the product.

As soon as the metal is set—with any form of chill—the wheels, while still red hot, are removed from the mould and immediately placed, by means

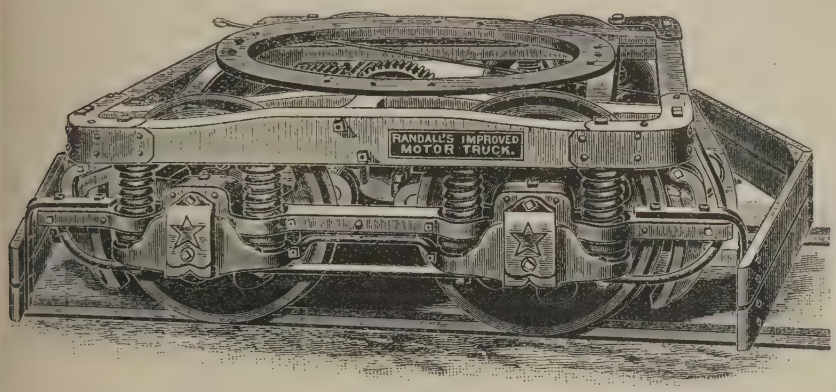


Fig. 456.—Truck for Eight Wheel Cars—I. H. Randall.

of iron trucks, cranes and tongs, in the annealing pits, where they remain four or five days, and are allowed to cool gradually, a process necessary to prevent cracking from unequal contraction.

The wheels, when sufficiently cooled, are removed to the scratching room, or placed under a sand blast where the moulding sand which may adhere to the metal is removed, when they are ready for shipment, unless their mechanical condition is to be improved by further treatment. A number of manufacturers follow up foundry practice by surfacing the tread of the wheels to remove any imperfections in rotundity and balance, or, in some cases, simply to remove the fins left by the slots in the contracting chills. Owing to the hardness of chilled metal, ordinary tools are unavailable for this work, so it is necessary to employ emery; and for performing the work specially designed machines are required, and these are of three different types. The first machine (Fig. 460) is designed for grinding wheels before mounting them on their axles. Heavy expanding mandrels are provided, upon which the wheels are placed and centered after being carefully bored ; then, as they slowly turn upon the mandrel, swiftly revolving emery wheels are brought up against the tread and grind it perfectly true. It is not necessary with this machine that the wheels be bored to finished size to fit their axles ; this can be done afterwards in the purchasers' shops, but it admits of making the wheels mechanically perfect at the foundry before shipment.

A second machine grinds the wheels in a similar manner after they are mounted upon their axles. The third machine is constructed with two or three grooved rollers placed in triangular position to each other, on which the rim of the car wheel rests, one of which, being driven, causes the wheel to revolve slowly by frictional contact. An emery wheel placed in a suitable position, and having in addition to its rotatory motion a shuttle motion equal to the width of the tread, grinds the chill fins from the tread and flange.

It is highly important that the wheels be made perfectly cylindrical, for if the wheel is not true the brake pressure will be greater at one point of the circumference than at another, resulting in the skidding or slipping of the wheel upon the rail, thereby producing a flat spot upon the tread which is rapidly enlarged thereafter, soon rendering the wheel unserviceable.

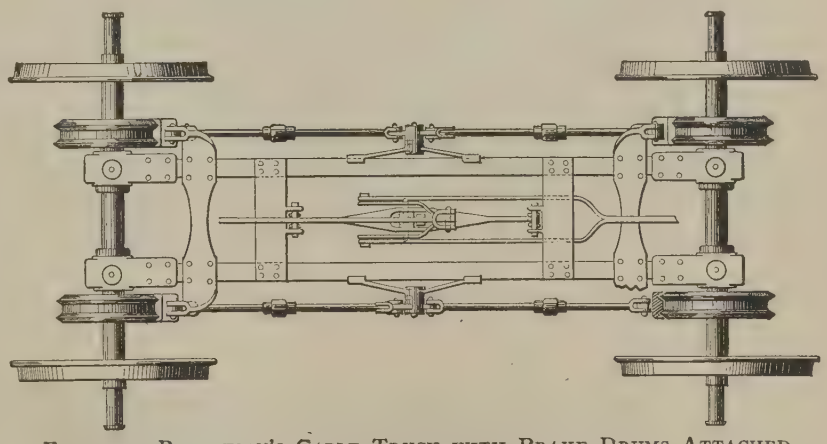


Fig. 457.—Robertson's Cable Truck with Brake Drums Attached to the Axles.

The process of manufacturing differs considerably in details in different establishments, special

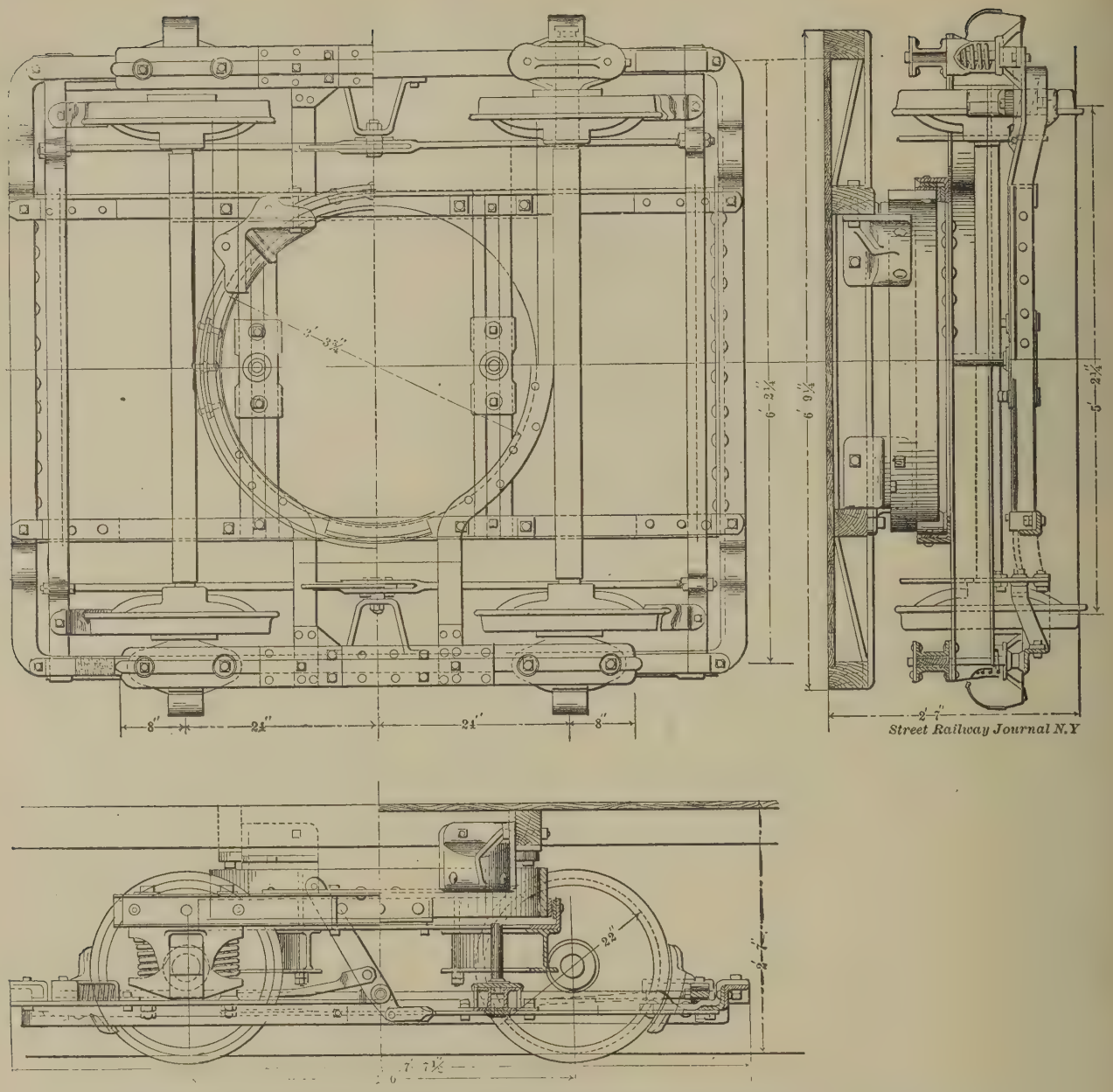


FIG. 458.—CABLE TRUCK FOR EIGHT WHEEL CARS—CITIZENS' TRACTION CO., PITTSBURGH, PA.

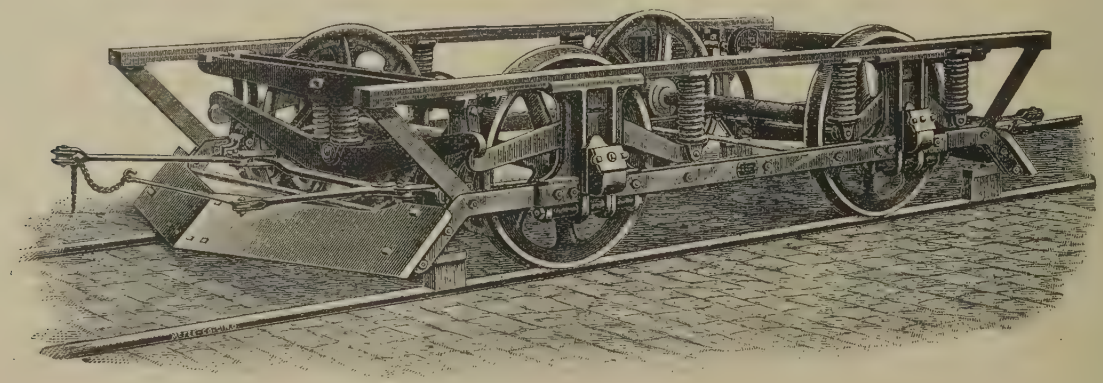


FIG. 459.—SHEFFIELD EQUALIZING TRUCK.

care being devoted by some to the nature of the raw material or mixture of irons used, by others to secure a perfectly cylindrical shape, while still others give special attention to annealing.

It is obvious that in a process based on such principles as are enumerated above, the qualities of the product depend largely upon the degree of care and skill exercised in the various stages of manufacture, ranking the business among the high est branches of the art of casting iron.

There is a considerable diversity in the depth of the chill of wheels made by the different manufacturers, the general range being from one-fourth of an inch, through the intermediate fractions to three-fourths of an inch, the latter depth being necessary for a serviceable motor wheel. The diameters of wheels for electric motors are thirty, thirty-three and thirty-six inches, and the weight varies from 300 to 425 lbs. For horse and trail car service the weight is from 180 to 200 lbs.; for cable service the diameters are twenty-two, twenty-four and thirty inches with the corresponding weights of 140, 160 and 240 lbs.

The patterns of wheels vary through a large range to suit the fancy of the truck makers, one firm, we are told, making more than twenty patterns of wheels for electric service. This is unfortunate, and it is hoped that a standard will be adopted in the near future.

All wheels are, presumably, subjected to a severe test, either by the manufacturers or the purchasing companies, or both, before they are put in service. The tests, however, are not as severe as in steam service, and usually no guarantee is required of the maker. In case it is found desirable to exact a guarantee, the specifications as to the design, essential points, inspection and manner of testing, may be modelled after those employed on certain steam lines as follows: "First that the wheel shall be truly cylindrical; second that the body of the wheel shall be smooth and free from shrinkage, slag or blow holes, the tread from deep and irregular wrinkles, and free from sand or slag. Wheels broken must show clear gray iron, free from noles containing dirt or slag more than one-fourth of an inch in diameter or clusters of such holes, and the depth of white or chilled iron must not vary more than one-fourth of an inch from the standard depth around the tread of the wheel."

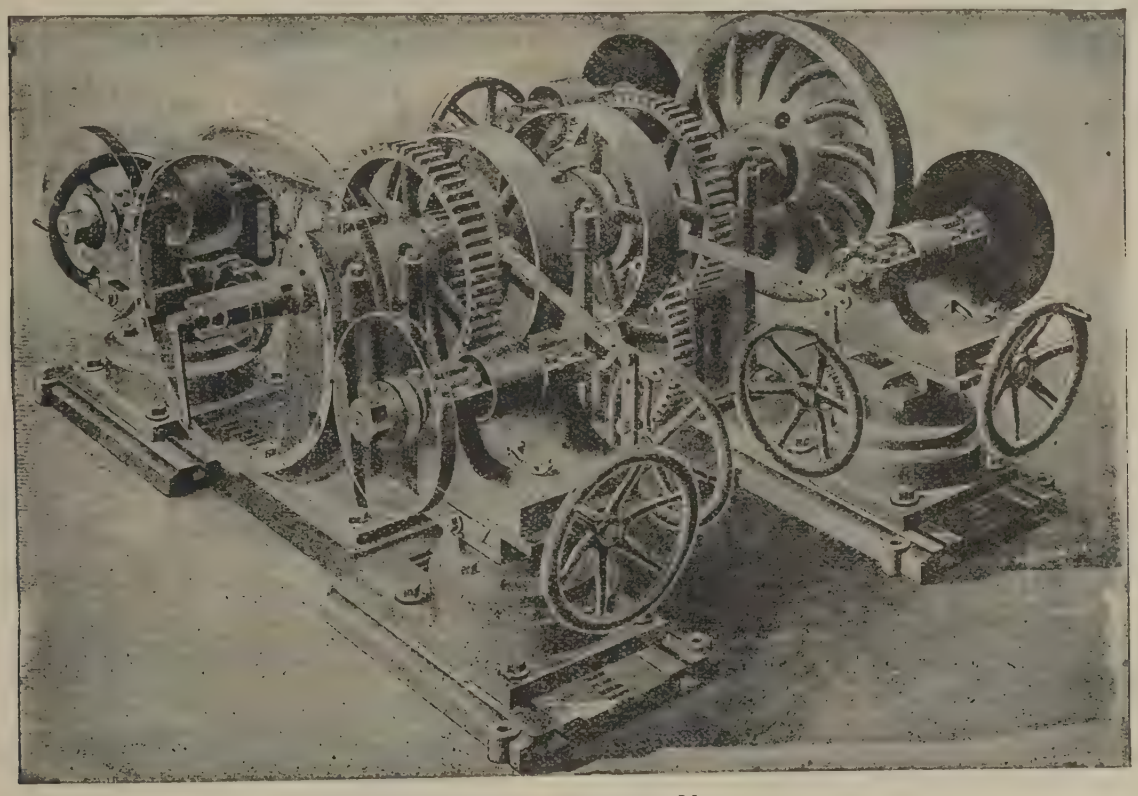


FIG. 460.—WHEEL GRINDING MACHINE.

The life of cast wheels in horse car service, under favorable conditions, is about one year, and they are usually good for a mileage of from 25,000 to 40,000. In some cases, however, a mileage of 70,000 has been obtained. Under trail cars the average mileage is not quite so high, owing to increased speed. A good average for the driving wheels of motor cars is 30,000 miles.

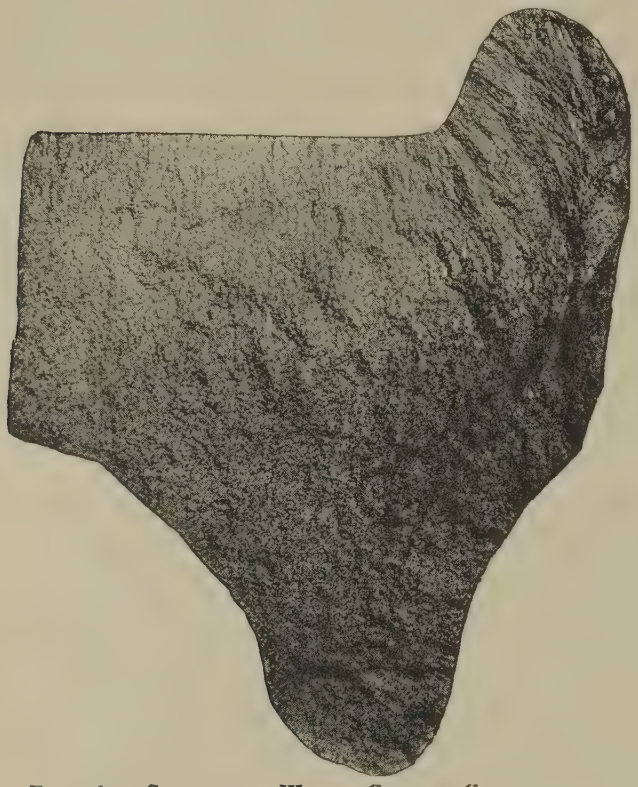


FIG. 461.—SECTION OF WHEEL CAST IN CONTRACTING CHILL.

Wheels are scrapped when broken, when the flange is too much worn or broken, when the chill of the tread is worn through, or when slid flat.

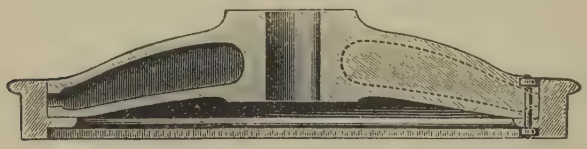


FIG. 462.—PAPER STEEL TIRED WHEEL.

Steel tired wheels are manufactured in various styles, but the process in most cases is too complex to be readily described. The various types consist of a steel tire shrunk and bolted to a web or core made of paper, cast iron or corrugated steel plates having a cast hub (Figs. 462 to 464). The merits of this type of wheel are noted above. As in the case of cast wheels, there is a notable difference in the respective merits of the steel tired wheels made by different manufacturers.

Solid steel wheels are cast from molten metal much in the same manner as iron wheels, except that chill rings are not employed. A peculiar method of pouring is adopted which insures a rim of uniform texture and entirely free from flaws or blow holes. After being cast the wheels are paired and the treads turned down to a uniform diameter.

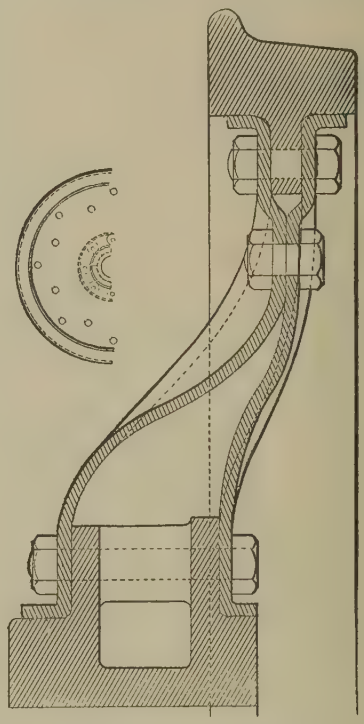


FIG. 463.—STEEL TIRED WHEEL WITH CORRUGATED PLATES.

FIG. 464.—STEEL TIRED WHEEL WITH CAST CENTRE.

It is claimed for these wheels that they do not break or crumble, and that when slid flat or they

begin to show wear, they may be "turned up" or returned for a nominal sum and made substantially as good and serviceable as new wheels, thereby increasing the life and mileage to an indefinite degree. It is also claimed that better traction is obtained with these wheels than with iron wheels and that the brake grips the wheels much better and stops the car more quickly. Solid steel wheels cost somewhat less than steel tired wheels, but about double the price of cast iron wheels.

AXLES.

With few exceptions street railway practice has been uniform with that of steam railway in reference to the mounting of wheels and axles, each pair of wheels and their axle being closely united and revolving together instead of the wheel turning round on the axle as on other vehicles. Although a great deal of inventive talent has been expended in attempts to obviate the difficulties attending the operation of loose wheels, no substantial progress has been made, and the method of placing wheels upon their axles by powerful hydraulic pressure or by adjustable clamps still continues and is likely to be followed for an indefinite period.

Many puzzling questions have arisen in steam railway practice in regard to the best methods of manufacturing axles, including the metal, shape and distribution of metal used, and much attention has been given to the subject, with great advantage, for a broken axle is one of the things most greatly to be dreaded in railway train movements. While the damage from a broken or bent street car axle is confined usually to the cost of replacing it and the time for which the car is out of service, it amounts to a large sum if breaks frequently occur, which, unfortunately, has been the experience heretofore on most electric lines; hence, the standards adopted for steam practice may be closely copied for electric service, for practice demonstrates that this service is as hard, if not harder, on axles than steam service.

Axle defects do not usually develop till after a certain period of service, but owing to the excessive weight and pounding and torsional strain, especially if the track is inferior, the axles bend or the metal becomes crystallized so that after a year or a year and a half of service frequent failures occur, unless a large factor of safety is allowed in the design, and even then it will doubtless be found to be economical to order motor axles into trailer service after a certain period, following the practice of some steam lines which direct that all axles, after eighteen months' passenger service be transferred to freight cars.

In steam service both forged and rolled axles are employed, and the forged axles are hammered both from muck bar, scrap, and directly from the blooms, but scrap is not employed in the manufacture of street car axles; these are hammered direct from the ingots or blooms. Rolled axles are more generally employed in street railway service, although quite a difference of opinion exists among street railway men in regard to the relative merits of the forged or rolled article for motor service. Opinions in some cases have doubtless been formed because of experience had with an inferior article; in one instance we are told "that axles rolled from mild steel are more satisfactory to work than hammered axles because they are not as liable to have seams or flaws," and in another, "forged or hammered axles are preferable to cold rolled, for the reason that in a well hammered axle the fibres are closely welded, and when the journals are turned down the surface is smooth and free from seams."

Axles rolled from open hearth steel with from fifteen to eighteen per cent. of carbon, if given proper dimensions, will be found of sufficient strength for ordinary service, and are considerably cheaper than the forged article. The best axles, however, are doubtless made from crucible steel out of Swedish charcoal iron; those made from Glendon steel are giving good results, and there are other mixtures that are recommended. The axle makers in some cases make their steel in accordance with specifications received from the truck makers.

It is often required that axles be surfaced down to the one-thousandth of an inch of the specified diameter, in order to provide a suitable support for the motors, and a proper seat for the gear wheels; hence it is highly important that the metal

be uniform and homogeneous. Axles should be rough turned all over before making any finishing cuts, as this will avoid the springing of the metal out of true, caused by releasing the strain which the skin exerts on the bar. In case one part is finished before dressing the entire surface, the parts will be out of true with each other, and trouble will be experienced from the heating of motor bearings. The key-seat should not be more than three-eighths of an inch deep, as a greater depth will tend to weaken the axle; the length will depend upon the width of gear employed.

Instead of surfacing axles upon a lathe as is ordinarily done "die drawn" bars may be employed. These bars after being rolled from the steel billets are drawn through a die, after the manner of making wire, and it is claimed that by this process the transverse and torsional strength is greatly increased and, that it imparts to the axle a harder, better polished and better wearing surface than can be produced by any other method of dressing. The manufacturers guarantee their axles accurate in size to within one-thousandth of an inch.

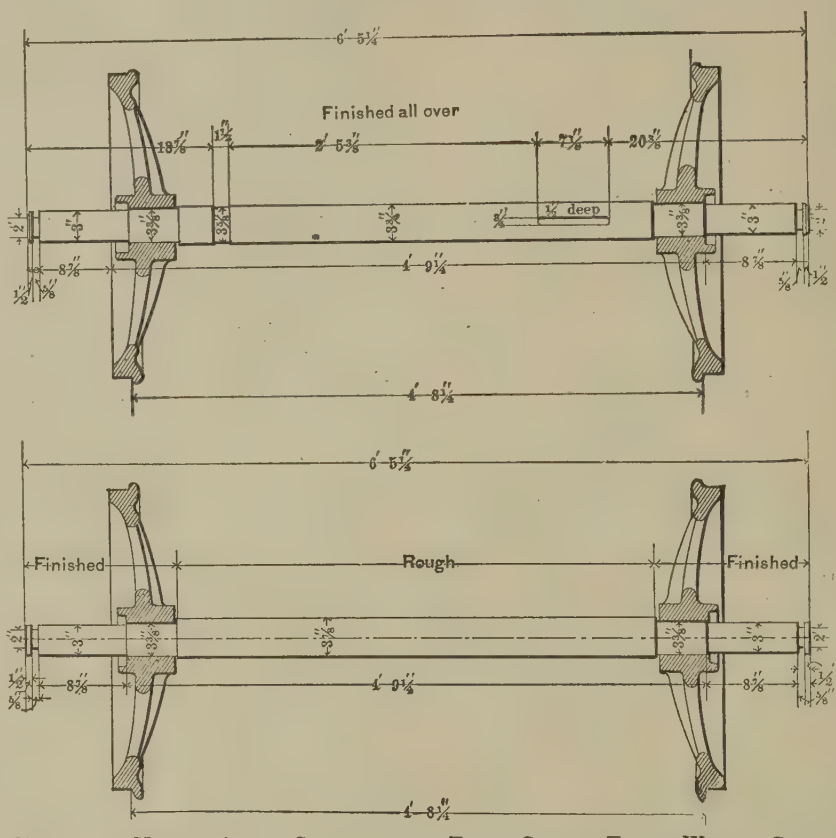


FIG. 465.—HEAVY AXLES SUITABLE FOR FOUR, SIX OR EIGHT WHEEL CARS.

Because of the necessity of dressing motor axles, not so much attention can be given to the shape of the axles between the wheels as is done in steam service, but great attention should be given to the dimensions of the body and journals, as the mistakes that have led to disaster in motor service have been in regard to dimensions rather than to the quality of the metal or method of manufacture. The severity of the service is very great, and while other parts of the equipment have been increased accordingly (the wheels, for instance, being fifty per cent. heavier than formerly) the diameter of the axles remains about the same, and is entirely too small.

While it is not possible to recommend a standard that will prove serviceable under all conditions, because the only test (long service) is wanting, still we can refer to the practice of some of the lines that have had several years' service and are modelling their present designs (Fig. 465) for additional equipment after the plain teachings of experience. Others find that a journal three and one-half inches in diameter, with the wheel seat four inches, gives generally better satisfaction (Fig. 466). Figs. 467 to 469 illustrate the dimensions of axles heretofore employed with different types of motors. The present tendency is in the direction of increased size. Of course, the diameter of axles will be influenced somewhat by the type of truck and motor employed and the diameter of the wheels, the thirty-six inch wheels being more severe on axles at the point of greatest strain (just inside the hub) than on the thirty or thirty-three inch wheels, and the radial trucks also require a heavier axle. Not only does the diameter of the wheel influence the design for the axle, but the type of wheel employed

should also be considered. In steam practice it is found that axles of the same dimensions have a much longer life when employed with paper wheels than with cast wheels. This is due, doubtless, to the wheels being somewhat elastic, so that they do not transmit the shocks to the axles. Similar claims are made for adjustable wheels that are cushioned upon the axle.

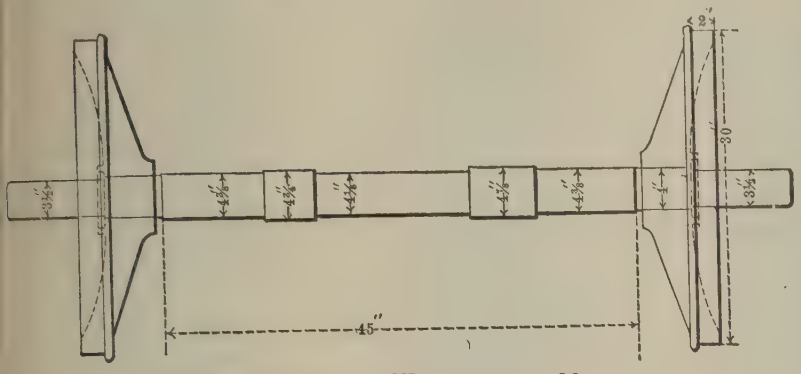


FIG. 466.—AXLE FOR WESTINGHOUSE MOTOR.

The journals should be enlarged to correspond with the increased diameter of axles; for sixteen foot bodies they should not be less than two and seven-eighths inches in diameter, and not less than three and a quarter inches for twenty foot bodies. The side edges of the brasses should be slightly rounded to allow for better lubrication, and the ends also, to prevent wearing a shoulder on the journal. About one-fourth of an inch lateral motion of axle must be provided for, as this will give the best results in relation to the keyways.

The journal boxes are usually so constructed as to be dust and oil tight and easy running, and it is vital to the success of any truck that they should be so, and that they should require oiling but once in six or twelve months. The brasses should last from five to ten years.

In designing trucks, attention should be given to cushioning all the parts as far as possible. This will be apparent when we consider that the non-elastic or dead weight per wheel of a sixteen foot electric car is about 800 lbs., counting the weight of the wheel, journal box, axle gear and one-third the motor. The total weight per wheel, with 100 passengers, would be in the neighborhood of 6,500 lbs. The force of a hammer blow increases directly as the weight; hence, it is easy to understand why the service of electric motors is much more severe upon the track and appliances than horse cars, and more severe even than steam locomotives.

SPRINGS.

Until recent years rubber was extensively used for all classes of railroad springs, but did not operate satisfactorily in cold climates. Following this era, a spring composed of a steel coil, inside of which was placed a cylinder of rubber, was generally employed. This type of spring was quite effective, and produced at much less cost than the barrel shaped rubber springs formerly used. To prevent the chafing of the rubber by the coils, cone shaped pieces of rubber were fitted in at each end of the coil, which allowed of the rubber spreading out under compression without coming in contact with the coils (Fig. 470).

FIG. 467.—AXLE FOR EDISON SINGLE REDUCTION MOTOR.

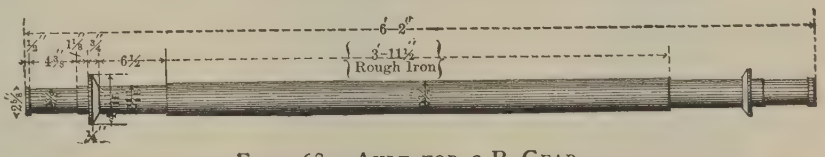


FIG. 468.—AXLE FOR 2 B. GEAR.

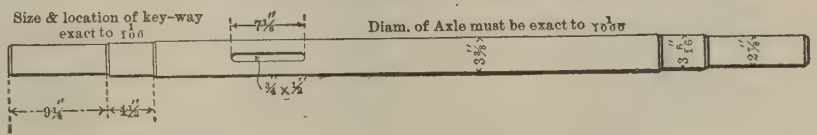


FIG. 469.—AXLE FOR T.-H. W. P. MOTOR.

By leaving a space between the two cones, so that they do not touch till quite a load is put upon the coil, a graduated spring is produced (Figs. 471 to 477). This allows the steel coil to carry the empty car, but brings the rubbers into service with the load. In case it is found desirable to reduce the elasticity of this type of springs, one rubber and one iron cone may be employed. The iron

cone assists in holding the springs more firmly to the bolt, and relieves the rubber cone somewhat from wear.

The principle of graduated springs is now quite generally employed in street car service, the graduation being effected, not only by the employment of rubber cones, which is the most effectual, but by the shape of the coil, some being keg shaped some cone shaped, while others are coiled from a tapering steel bar (Figs. 475 to 477). In operation, the large coils of the keg shaped springs act under a light load, and as the load is increased the small coils come into action as they decrease in diameter.

In providing a graduated system of springs in connection with an extension of spring base to prevent the end oscillations of the car body, both spiral and elliptical springs are employed on certain types of trucks with satisfactory results (Fig. 443). Some makers employ only elliptical springs (Fig. 442). These do not have so wide a range as the spiral springs, but are thought to sustain the body more firmly, and prevent side oscillations.

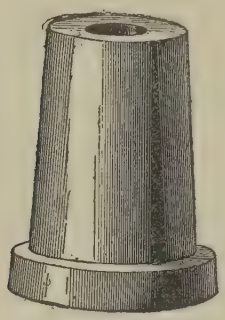


FIG. 470.—RUBBER CONE FOR GRADUATED SPRINGS.

FIG. 471.—RUBBER CONE SPRING FOR PEDESTAL GEAR.

FIG. 474.—RUBBER AND IRON CONE FOR PEDESTAL GEAR.

FIG. 475.—KEG SHAPE SPRING—FLAT BAR.

Spiral springs are not only employed for supporting the car body, but for brake release, drawbars, and other functions in motor trucks.

The manufacture of springs is an important industry, and a number of large firms are engaged in their production. The making of a reliable spring for motor service requires considerable skill, and, like nearly all the other truck appliances, has been undergoing a process of evolution, until now —thanks to the genius of the manufacturers—an article is produced that satisfies, in nearly all respects, the demands exacted by this particular service.

FIG. 472.—RUBBER CONE SPRING FOR POST GEAR.

FIG. 473.—SPIRAL SPRING WITH RUBBER AND IRON CONE FOR POST GEAR.

FIG. 476.—CONE SHAPE SPRING—ROUND BAR.

FIG. 477.—KEG SHAPE SPRING—ROUND BAR.

The details of the manufacture of a spiral spring are generally simple, with the exception of the tempering process which requires great care and skill, to be had only by long experience. The steel bar, either round, half round, oval or square, is rolled in the ordinary manner, when the ends are forged to a taper, and after being heated to a proper temperature it is coiled upon a mandrel having the desired shape. The coils are then tempered by being raised to a proper temperature, when they are immersed for a short time in a vat of oil, and then allowed to cool naturally; or the flash process may be employed, which consists in dipping the hot spring into oil, and, while ablaze, whirling it through the air, thus suddenly extinguishing the flame and cooling the metal. In order to secure a uniform temper in a lot of springs, it is the practice in some establishments, after tempering as above, to place them in a specially designed furnace which is maintained at a certain steady heat, and as they come through allowing them to cool naturally. The testing process then follows, each spring being subjected to compression under a plunger, the height being carefully measured before and after the operation in order to detect any permanent set. It is also carefully inspected to see that cracks or flaws are not developed.

The varieties and patterns of spiral springs are quite numerous, and include not only those made from bars of different cross sections, but those known as double and triple coil springs.

The advantages of springs, as one of the truck appliances, are not confined to the comfort of passengers merely, but they preserve both the body and the road bed from injury due to concussion, and they assist in surmounting obstacles by allowing the passage of the wheel over them while the suspended weight is scarcely lifted from its level.

Since springs serve such important ends and conduce so much to the comforts of travel, we can hardly realize that it is only about sixty years since springs of any kind were employed on railway vehicles, and only a few years since the spiral spring was invented.

GLASS AND ITS PREPARATION.

Glass in large quantities enters into car building, and is employed for window, door and deck lights, also for Gothic windows and mirrors. Plate glass, of a quality suitable for ordinary glazing and for silvering or embossing, is made in this country, but English and Belgian plate are considered better suited for the finest mirrors.

The process of embossing glass is about as follows: The naked pane of glass is first heated to a temperature of about 120 degs. by being put in a pit over coils of steam pipes. A coating of a compound made of beeswax and rosin is then spread over the upper surface, and over this a sheet of tinfoil is placed, to which it adheres quite firmly, and after cooling, the foil is covered with dark paint. A tracing of the required design is then made on the blackened surface by means of a stencil plate and chalk dust. Then by means of sharp needles the portions of the lead foil necessary to show on the glass the figures and designs to be etched, are cut out. This work may be performed by young girls. The under side or back of the pane is then covered with paraffine, and with its covering is immersed in a bath of fluoric acid, which in the course of an hour eats out the exposed portion of the glass to the depth of one thirty-second of an inch, but has no effect upon the covered portions. The surface of the pane is then ground, which renders the raised portions translucent while the etchings remain perfectly transparent. Another process is sometimes followed in which fluoric acid and ammonia are employed, which render the exposed portions translucent.

In case the figures of men, animals or landscapes are desired, these may be painted in free hand upon the glass, the paint serving the purpose of the tinfoil in protecting the covered portions from the effect of the acid. The glass, being taken from the bath, is again heated to remove the wax and tinfoil, when it is thoroughly cleaned with soda water, dried and made ready for the glazier or for silvering, if portions require silvering. To protect the hands from injury while working the acid bath, workmen usually wear rubber gloves. Glass is also ornamented for car purposes by the sand blast

process, by which means there are brought out upon the surface of the glass most exquisite representations of the tendrils, sprigs, leaves and flowers of the daintiest plants.

Bevelled glass is made by grinding off the corners of the plates successively upon horizontal iron wheels sprinkled with fine sand, then upon a similar wheel covered with emery, then upon a horizontal grindstone having a peculiar grit, next upon a wooden wheel, and, finally, the edge is perfectly polished upon a wheel covered with felt and rouge.

Mirrors are made, preferably, as before stated, of English and Belgian plate glass. In the process, the plates are first cleansed with water and then polished with rouge (oxide of iron), which removes any surface defects. It is then heated by being placed upon a grated platform over coils of steam pipe, and the upper surface is covered with a solution of nitrate of silver and chloride of calcium, when the metallic silver is precipitated, and deposited upon the surface. The glass is then carefully washed, and after drying, the back is covered with a coat of red lead, and afterwards bronzed so that the silver is protected from oxidization.

Old mirrors may be renewed by first removing the paint by means of a lye bath, and then the metallic silver by means of nitric acid, when it is treated as above described for new glass. The silver for the mirrors is purchased in the form of nitrate crystals.

METALLIC TRIMMINGS.

These are usually of bronze, and are sometimes plated or japanned. They include such articles as locks, hinges, door knobs, change wickets, dash and body grab handles, brake handles, door handles and holders, window guards, litts and catches, window blind lifts, sash springs, deck sash pivots and openers, ventilator openers, rail brackets, bells and gongs, bell strap guides, seat arms and standards, hooks, etc.

Trimmings ready for use are usually purchased from dealers who make a specialty of this line of work. Some shops, however, manufacture their own trimmings, which are turned out from specially prepared patterns.

The process of manufacture may be described as follows:

The material, which consists of copper, tin (English block) and zinc, is mixed in certain proportions, depending upon the desired quality of the product, and melted in small crucibles over sunken furnaces such as are commonly employed in brass foundries. The moulding is done in small iron flasks with a specially prepared moulding sand. Each flask may contain matrices for a large number of small parts so connected that the metal will fill each when poured through one or two openings. Long rods, such as dash rails and window rods, may be moulded straight or in coils and afterwards straightened. The coils can be straightened without fracture, provided the proper mixture of metals is employed. From the foundry the castings are placed in the "tumbler" which is commonly an iron barrel, which, being made to revolve on its axis, causes the parts to chafe against each other till the rough surfaces are worn smooth. This process is sometimes hastened by the admission of water which can be introduced through hollow journal bearings. The parts next go to the filing and drilling department where the rough corners and ears are filed off and the screw holes are drilled and countersunk. The polishing follows, and this is done in the buffing department, which usually occupies a room by itself. First, the parts are ground smooth upon an emery belt or wheel against which they are held by hand, and are then further treated upon a leather bound wheel covered with fine emery or other polishing powder. The process continues through six or seven hands, and the trimmings are finally burnished upon a wheel formed of canvas discs upon which a little rouge is placed. The trimmings, except such as are to be plated or japanned, now bright and shining, are lacquered and baked and wrapped in tissue paper and taken to the store room. A silver and nickel-plating department is provided with vats containing a solution of nickel salts or sulphate of copper, in which the trimmings to be plated are placed for about twenty minutes. The electric current for this work may be generated by a dynamo operated

for the purpose, or may be obtained from the lighting plant or a galvanic battery. After the plating the parts are thoroughly washed and dried. The japanning of trimmings is done in the ordinary manner. In some well regulated establishments slanting shelves or vertical boards are provided in the store upon which samples of every pattern of trimmings are kept, numbered and named for ready reference.

THREE PLY VENEER.

A great variety of goods are embraced under this heading, and include seats, backs, ceilings, sides and panels. The manufacture of veneers is usually a process by itself, and car builders in most cases purchase the finished product from dealers. A few large car building establishments, however, manufacture it for their own use. The woods from which three ply veneers are usually made are maple, birch, oak white wood and mahogany. The veneer, with the exception of that made from oak and mahogany, is shaved from the surface of a log by means of long knives against which the log is made to revolve, the shaving being from one-twentieth to one-eighth of an inch thick, and of any length and width, depending upon the diameter and length of the log. This process is done in the neighborhood of the growing timber, and the material in rolls and sheets is shipped to the veneer factory. The oak veneer is sawn from the log, which is first quartered lengthwise, and the quarters are then sawn into thin strips, beginning at the centre. The best material for oak veneer is obtained from dead trees from which the sap part has decayed.

At the veneer factory the material is cut into strips, small pieces being jointed and fastened together by narrow pieces of glued paper. The strip designed for the middle ply is so cut that the grain of the wood runs lengthwise, while those for the outside plies have the grain running crossways. This arrangement of the grain in the three parts gives great strength to the finished veneer. The strip designed for the middle ply is now led through a pair of glueing rollers, in which both sides are thoroughly covered with a coat of hot glue, when it is placed between the two outside sheets, and the three are quickly transferred to thick wooden moulds or cauls which are then placed in powerful presses, where they remain until the glue is set and the ply becomes rigid, so that it will remain in the form (flat or arched) given it by the caul. The flat pieces are now dressed and polished in a sandpapering machine and the curved or waved surfaces are scraped and dressed by hand. They are then made ready for varnishing and decorating, or for the perforating bit, in case they are designed for seats or ventilated ceilings.

CAR SHOPS.

The arrangement and equipment of shops for the building and repair of cars will depend largely upon the amount of work to be done, and whether the product is for the trade or for home consumption Repair shops are a necessary adjunct of every well regulated street railway, and whether a company builds its own cars or not (a practice which is not recommended) repairs sometimes amount to the same thing, especially when two short cars are spliced together into one long car, a practice which is now quite common. The following particulars apply to shops in general, and may be modified to suit any particular case.

The success of any manufacturing enterprise depends upon its compliance with the laws of rigid economy and industry, the adoption of the most approved processes in the preparation of the material, the use of the latest improved machinery, tools and appliances, and the employment of workmen thoroughly bred to the business, who will fit all parts with exactness and nicety. To this may be added the employment of each set of workmen only upon one special branch of work (for which they are paid by the piece, by the hour or by the day) so that each shall attain perfection in his particular division, then holding the foreman of each department personally responsible for any defects that may occur in the work turned out from his department. The above presumes that the proprietors have had long experience and a reputation for honorable and fair dealing with their customers.

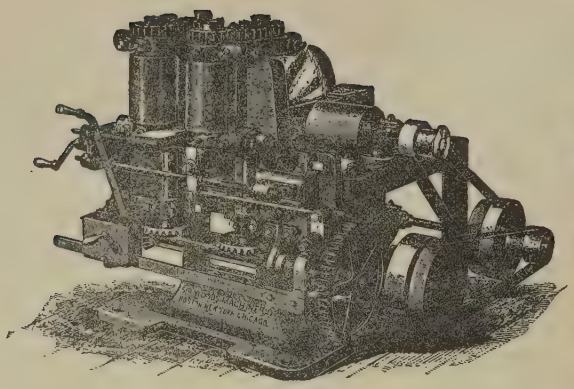


FIG. 478.—CIRCULAR RE-SAWING MACHINE.

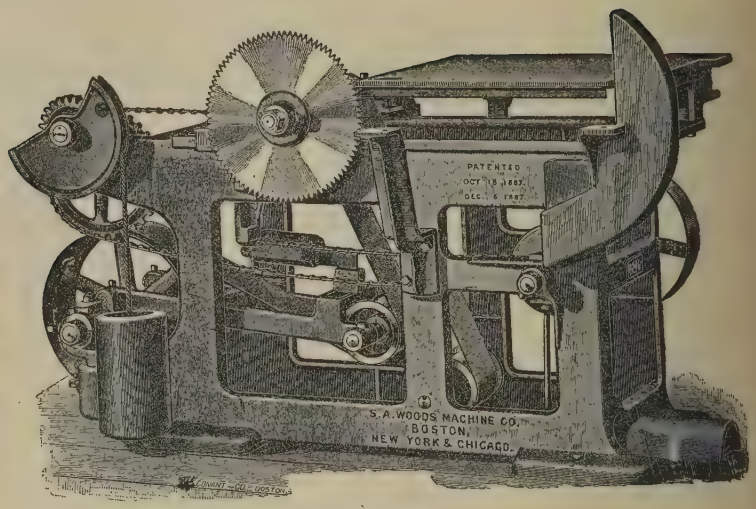


FIG. 481.—POWER FEED RAILWAY CUT-OFF SAW.

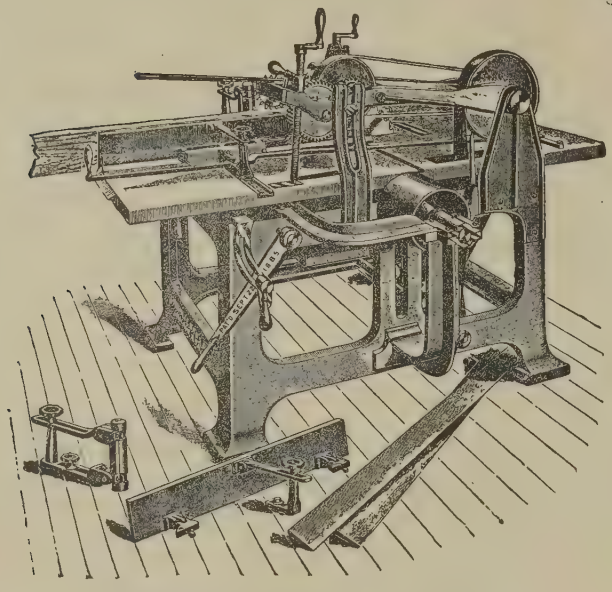


FIG. 479.—SELF-FEED SAW TABLE.

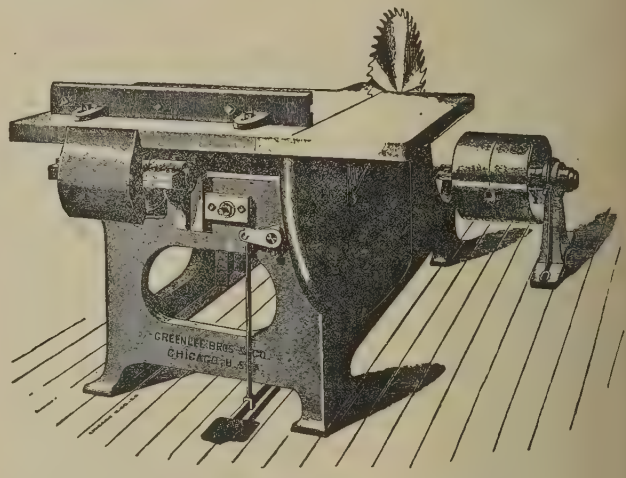


FIG. 482.—AUTOMATIC CUT-OFF MACHINE.

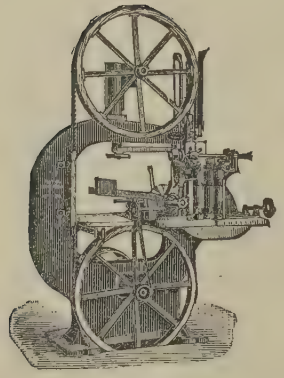


FIG. 480.
COMBINED SCROLL AND RE-SAWING BAND SAW.

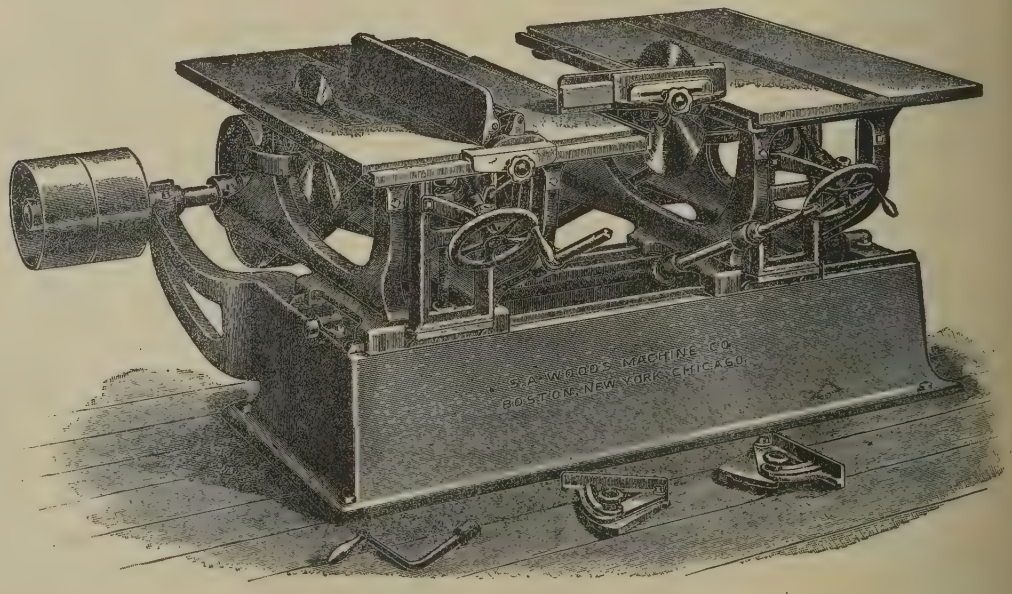


FIG. 483.—DOUBLE ADJUSTABLE CUTTING UP AND RIPPING SAW BENCH.

If a new business is to be established, great attention should be paid to the modelling and arrangement of the buildings to be occupied, and their location with reference to shipping facilities both for material and product. When it becomes necessary to occupy old buildings these should be

THE GENERAL OFFICE,

which may occupy a building by itself or one of the main buildings, should be equipped with all necessary office furniture and safes, and be furnished in as tasty and inviting a manner as the business can afford. Separate apartments are prefer-

FIG. 484.—SWING SAW.

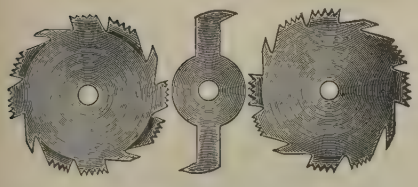


FIG. 485.—PATENT ADJUSTABLE SAW DADO HEADS.

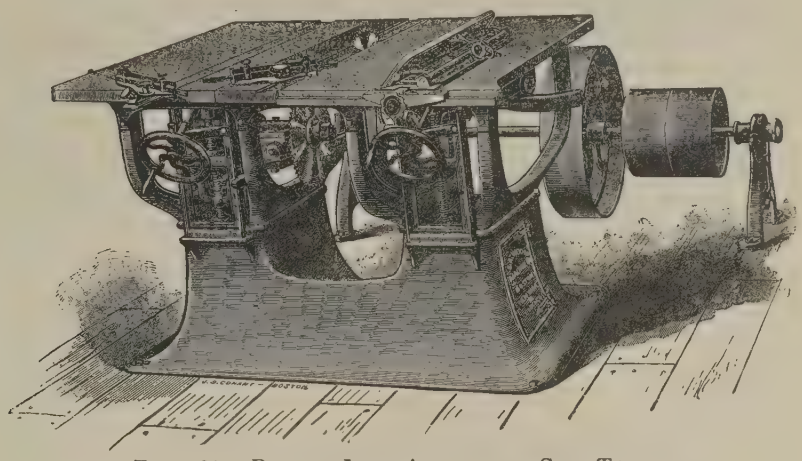


FIG. 486.—DOUBLE IRON ADJUSTABLE SAW TABLE.

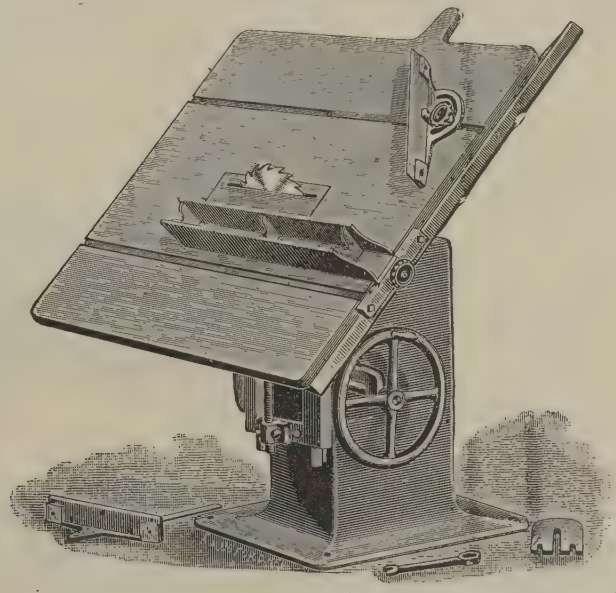


FIG. 487.—VARIETY SAW BENCH—FRANK H. CLEMENT CO.

remodelled to suit the business as far as possible. One, two or three story buildings may be employed, depending upon the value of property and the amount of space the plant is to occupy. Light, warmth, the exclusion of dust, and the adoption of such other means as will conduce to the health of the workmen, should be carefully considered, while no little attention should be given to protection against fire.

ably provided for the time keeper and bookkeepers, and a comfortable reception room should not be overlooked. The toilet arrangements, including closets, wash basins and lockers, are important and should be ample and suited to the force employed.

THE DRAUGHTING

department usually occupies rooms in the vicinity of the office. These should have ample light and be furnished, according to the magnitude of the

business, with draughting tools, tables, cases of drawers, safes or fireproof vaults for the preservation of all important drawings and specification details. A photograph or blue print room is also a necessary adjunct to the draughting department of a car shop.

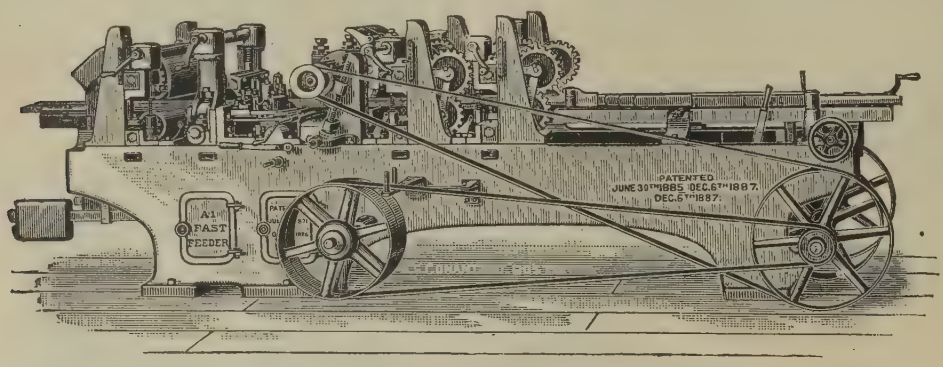


FIG. 488.—FOUR SIDED PLANER—FAST FEED FLOORER.

THE STORE ROOMS

may be apartments near the main office and may be located on the ground or other floors, depending upon the character of the different classes of material. Each should be in charge of a keeper who should deal out materials only on the written order of a shop foreman, which order should specify the number of the car order for which it is wanted, a receipt in all cases being required from the party to whom the material is delivered. Heavy parts, such as the malleable iron castings, journal boxes, springs, etc., are preferably stored on the ground floor, for which suitable bins and shelves, numbered and classified, should be provided. The store rooms for lighter parts may occupy some of the upper floors, and should be served by elevators for the speedy and safe transfer of the materials. The bolts and nuts, properly sorted and classified, may be stored in small bins or pockets, each of which should be numbered and lettered to correspond with the dimensions of the particular piece for which it is designed. Metallic trimmings should be stored in closed boxes, classified and arranged upon convenient shelves.

Canvas, duck, curtains and upholstering material are preferably stored on spools and mounted in convenient positions, to be readily unrolled, measured and dealt out. Store rooms for this material are usually located near the upholstering department, which is supplied with cutting tables, sewing machines, and other necessary appliances for making curtains, cushions, etc.

TRANSFER TRUCK TRACKS

and elevators are essential features of any car works. The first should be conveniently located and equipped with transfer tables of sufficient capacity to deliver the car body while in process of construction, from one department to another. The second should communicate with every building, storehouse or yard, and be provided with flat trucks and cars to facilitate the transfer of material. Tracks should not only communicate with the buildings, but the floors of each structure should have tracks of uniform gauge with numerous turntables, by means of which cars or material can be shifted about, and, by means of the elevators, be transferred from floor to floor.

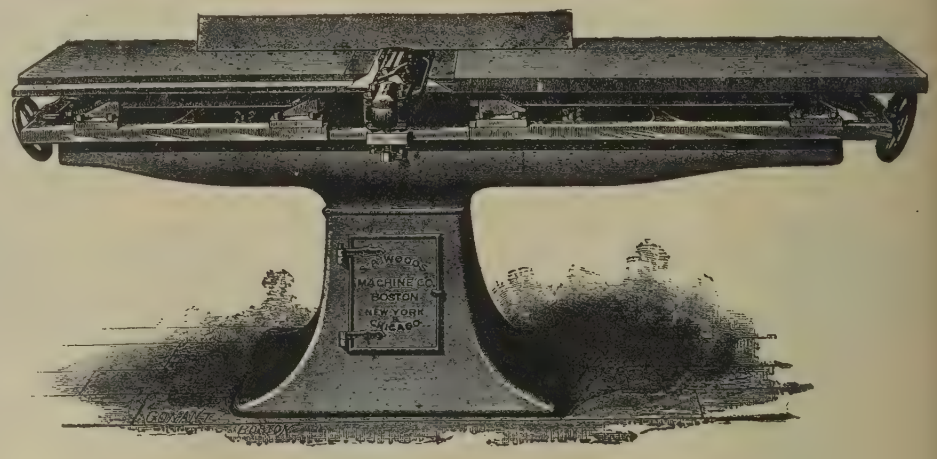


FIG. 489.—BUZZ PLANER.

THE LUMBER YARD

will necessarily be located where space can be had,

sometimes, in large cities, at some distance from the works. It is preferably located, however, within

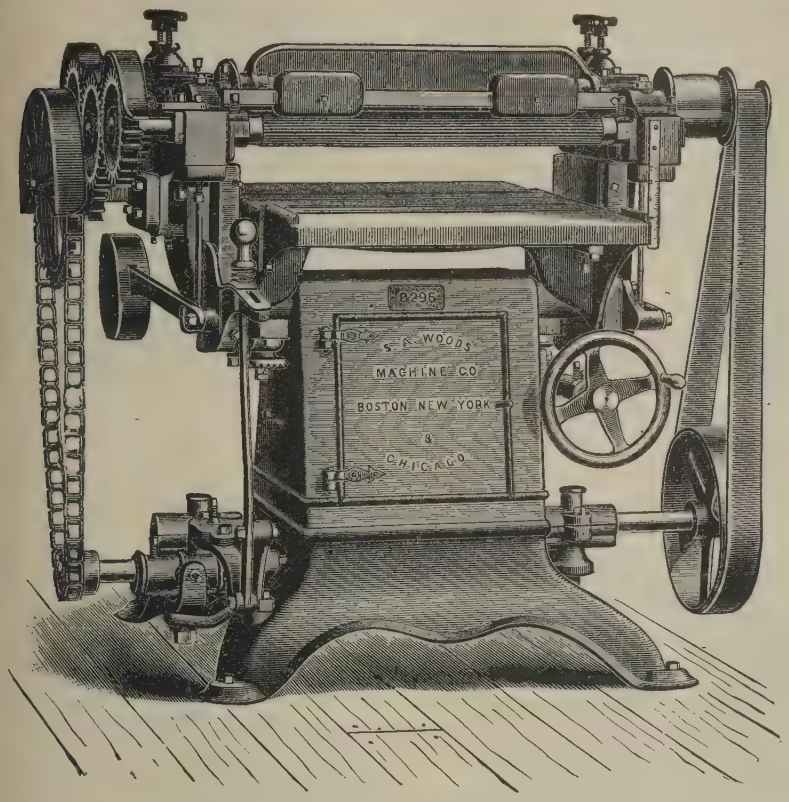


Fig. 490.—Pony Planer for Light Surfacing.

the same enclosure as the works. The lumber should be piled in sorts, and for the finer grades both open and closed sheds should be provided, the sheds being partitioned and divided into stories of suitable height to provide for housing a great variety of material in position to be readily accessible. A few closed sheds are necessary for the storing of kiln dried lumber.

A DRYING KILN

is a necessary adjunct of the lumber yard, and is preferably constructed with apartments or ceiled chambers with tight closing doors. The heat can be obtained from the exhaust steam of the power plant by leading it through coils of pipe in a separate chamber, and providing a power fan for driving the heated air through the flues which communicate with the drying chambers. The inlet and discharge flues should be provided with gates or valves, so that the temperature of each chamber can be regulated to suit the conditions of the stock. The material should be piled in open order in the chambers and each chamber should be provided with a thermometer. A record of the stock, including the kind, amount and date of being placed in the kiln, may be conveniently kept by having a slate attached to the outside of the door of each chamber and housed in with a glass in front. A second kiln for seasoning the cabinet material is provided in many shops, and in some cases this is located directly above the boilers of the power plant, so that the radiated heat of the boilers is utilized for drying purposes. In other cases the blast fan is placed near the boilers, and the kiln is located in an adjoining department.

A steam chest and bending appliances are also adjuncts of the cabinet department.

THE POWER

for operating the machinery of car shops is usually derived from a steam plant. This should be conveniently located so that by shafting or belts the power can be transmitted to the different departments. Repair shops are frequently operated by power from the stable plant which also operates the mills for grinding and cutting the feed. Electric motors are employed to good advantage

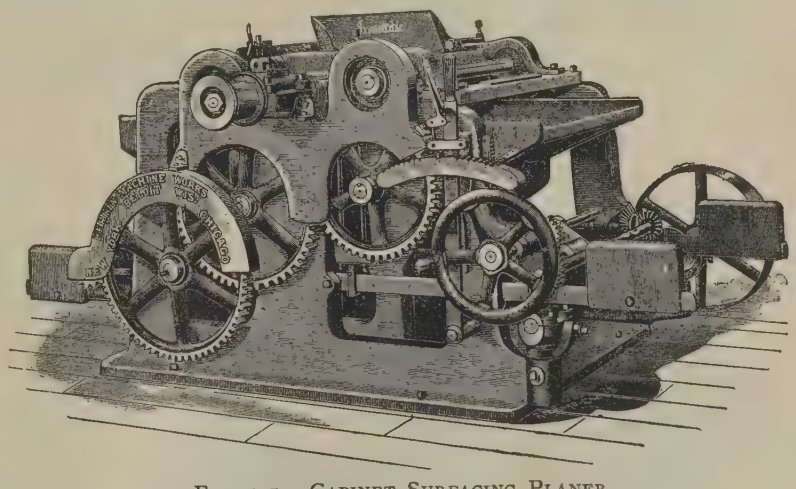


Fig. 491.—Cabinet Surfacing Planer.

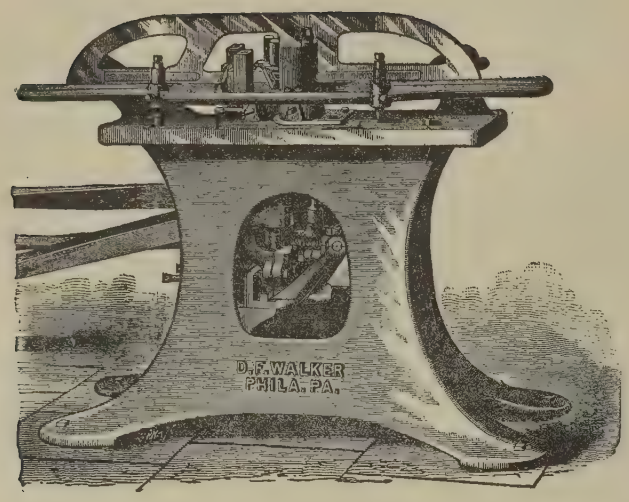


FIG. 492.—PANEL RAISING MACHINE.

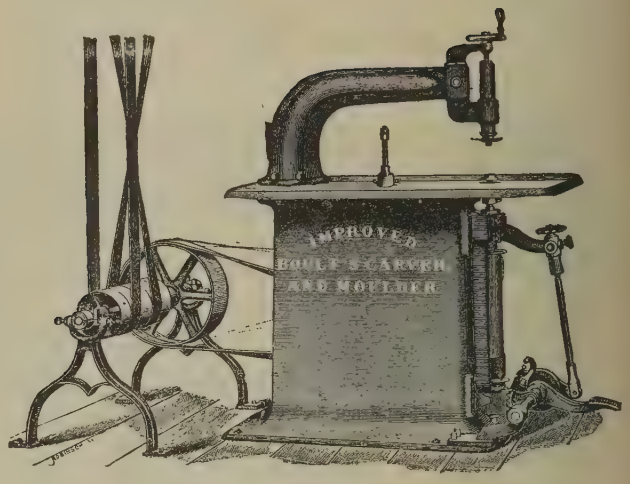


FIG. 495.—CARVER AND MOULDER.

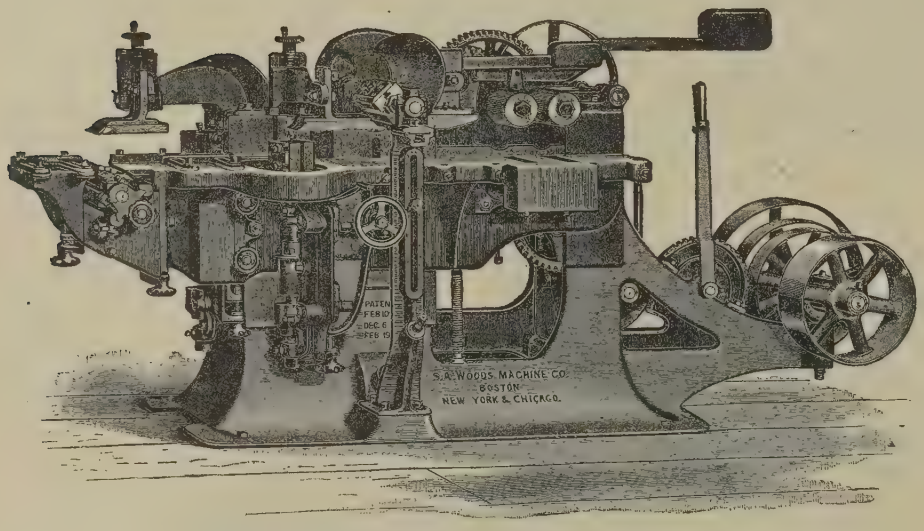
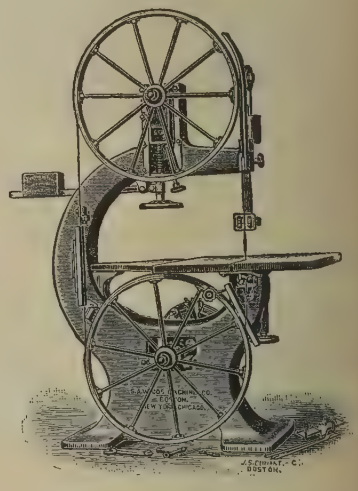


FIG. 493.—SEVEN INCH MOULDING MACHINE.



FIG, 496.—BAND SAW.

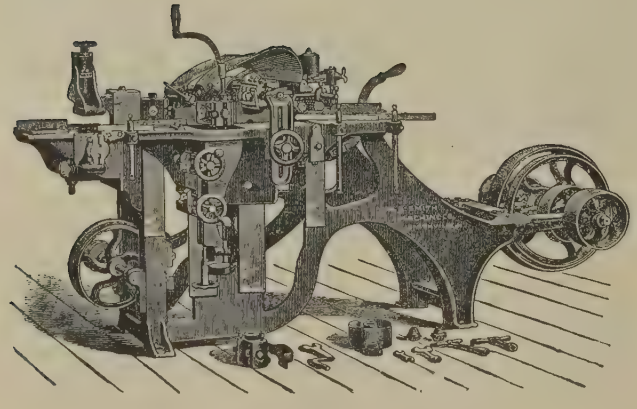


FIG. 494.—MOULDING MACHINE.

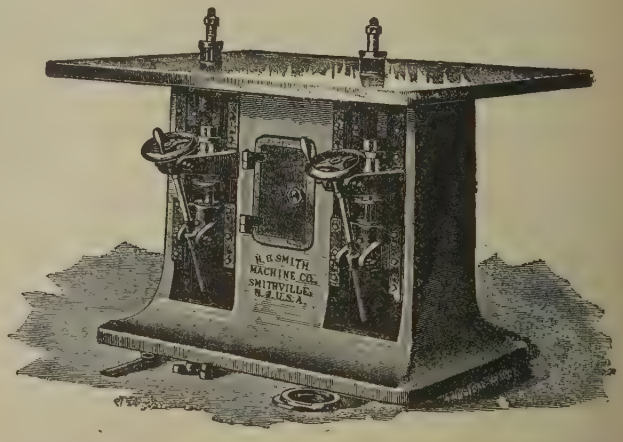
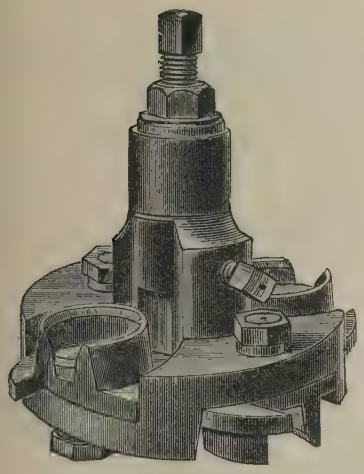
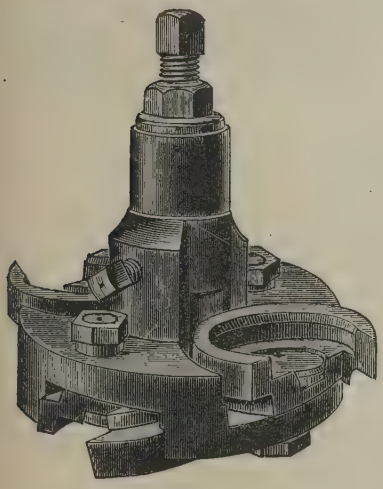


FIG. 497.—DOUBLE SPINDLE VARIETY MOULDER AND SHAPER.



Groove Head.



Tongue Head.

Fig. 498.—Shimer's Matcher Heads.

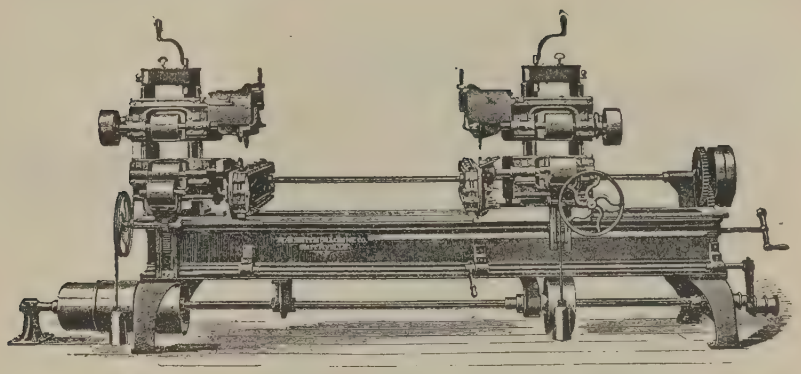


Fig. 500.—Heavy End Tenoning Machine with Double Heads and Copes.

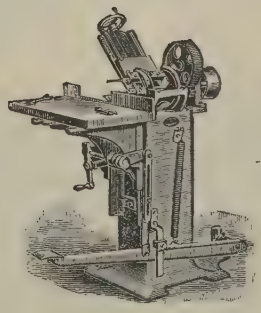


Fig. 501.—Double Dowel Borer.

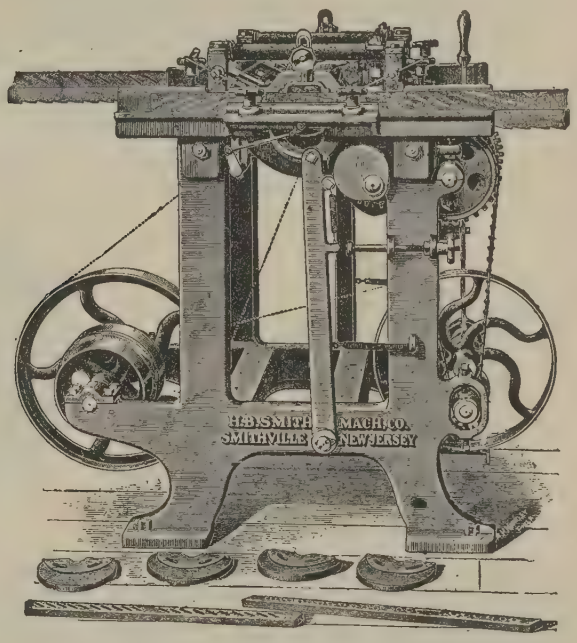


Fig. 502.—Blind Stile Mortiser and Borer.

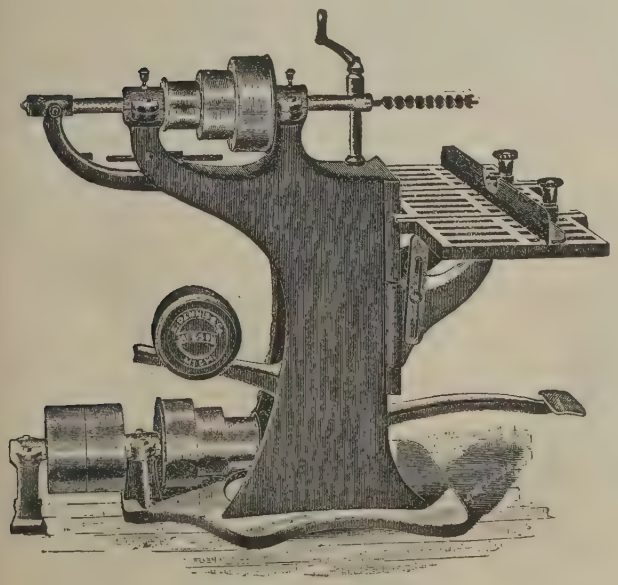


Fig. 499.—Single Spindle, Horizontal Boring Machine.

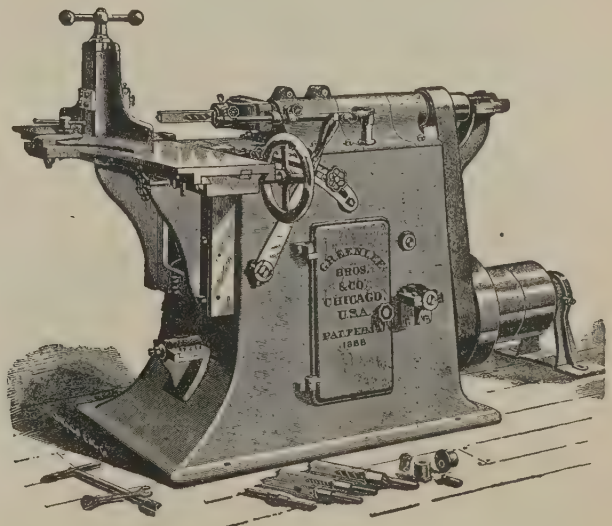


Fig. 503.—Hollow Chisel Mortising Machine.

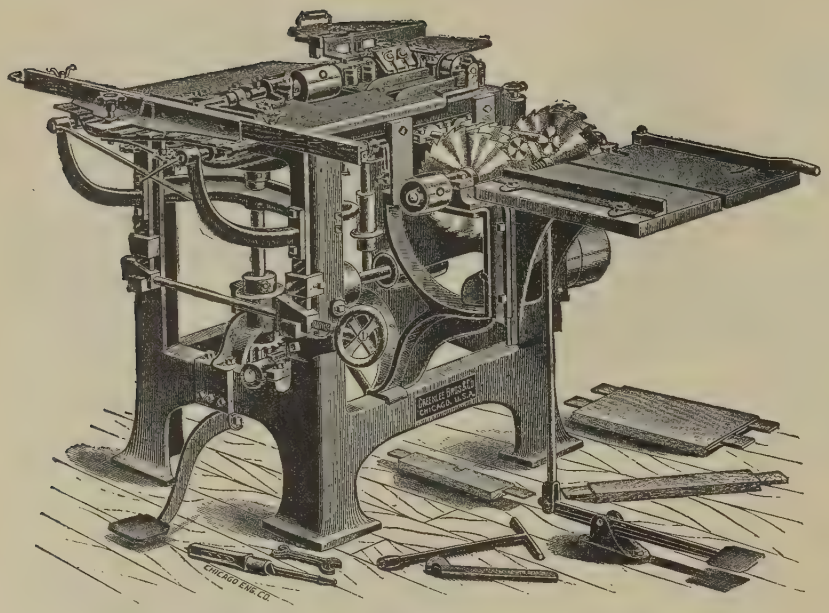


FIG. 504.—RELISHING AND MORTISING MACHINE.

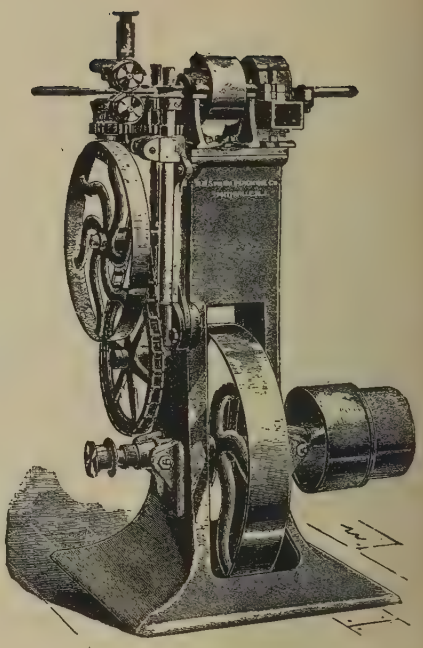


FIG. 507.—DOWEL MACHINE.

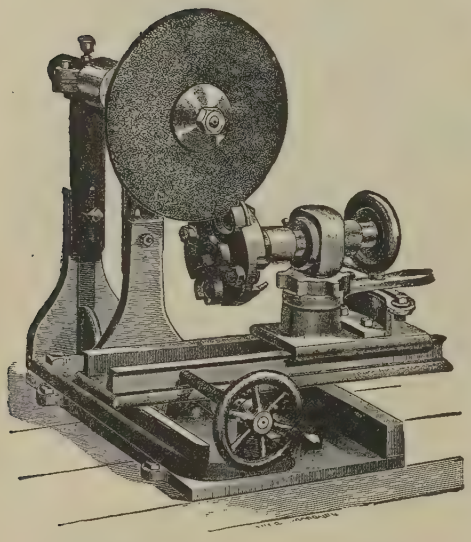


FIG. 505.—SHIMER HEAD, GRINDER.

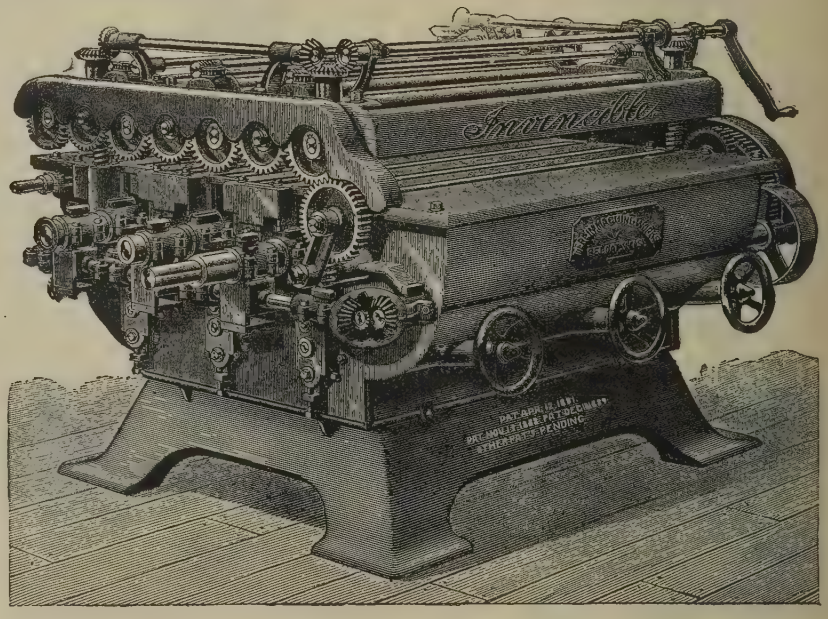


FIG. 508.—SANDING MACHINE.

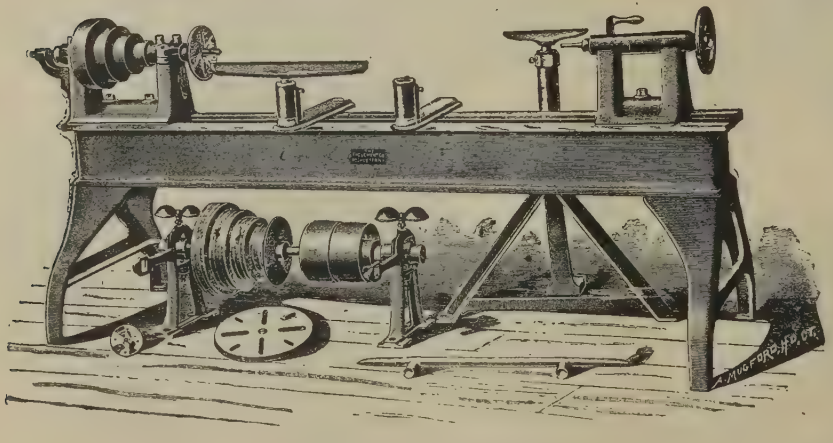


FIG. 506.—WOOD LATHE.

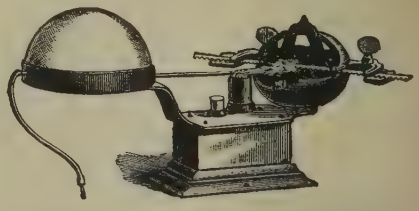


FIG. 509.—BAND SAW BRAZING LAMP.

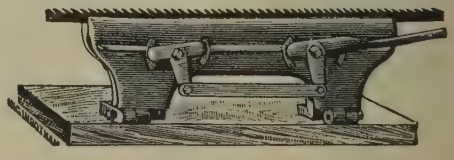


FIG. 510.—BAND SAW FILING VISE.

in some shops while a few depend upon horse power.

THE HEATING AND LIGHTING

is also a function of the power plant, and by having the different buildings properly equipped with piping, either for direct radiation or the blast system, the exhaust steam may be utilized for warming purposes. An electric light plant is a desirable feature in the car shop equipment, for it is frequently necessary to continue the work at night. Arc lamps should be conveniently located for lighting the yards and approaches, and both stationary and portable incandescent lamps should be provided for bench and inside car work.

THE WOOD WORKING DEPARTMENT

is one of the most important in car building, and upon its location, equipment and management the success of a business largely depends. It may occupy a building by itself on the first or second floor of a building in which other departments are located. In any event it should be thoroughly partitioned off, that all the dust may be confined within its own limits. It is highly important in the arrangement of machinery in this department that ample room be given to each machine, so that all may be operated at the same time without interfering with each other or with the operatives; also, to provide that all the work may be done on the in-

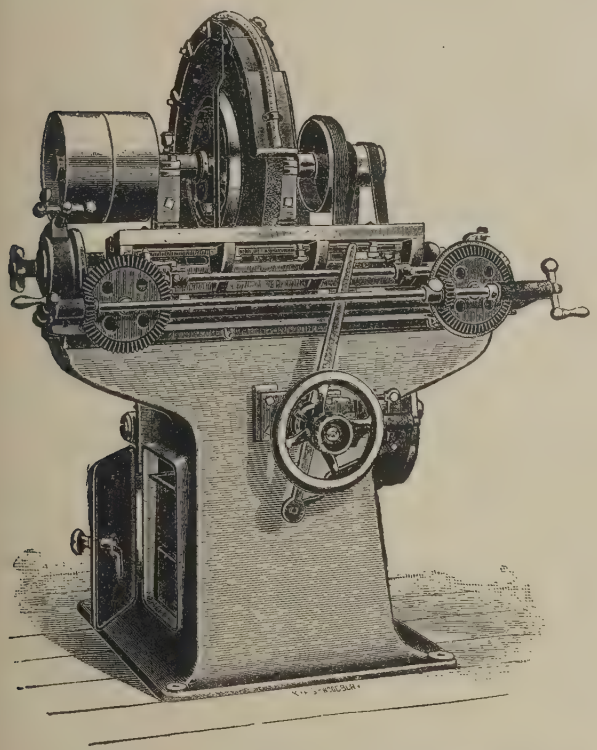


FIG. 511.—AUTOMATIC KNIFE GRINDER.

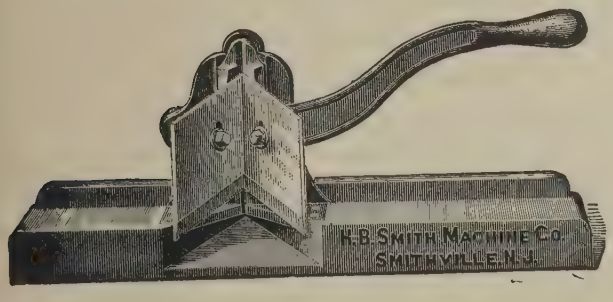


FIG. 512.—HAND MITRE MACHINE.

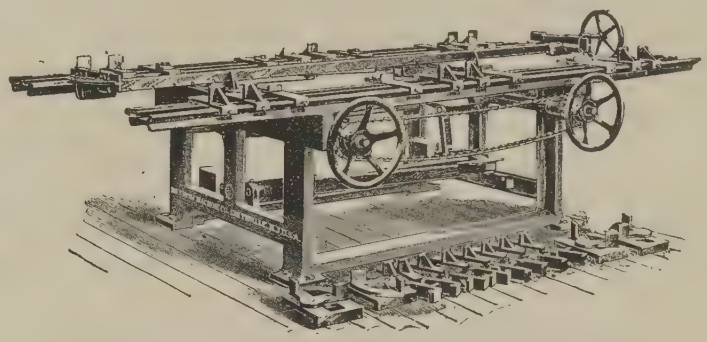


FIG. 513.—DOOR AND CABINET CLAMPING MACHINE.

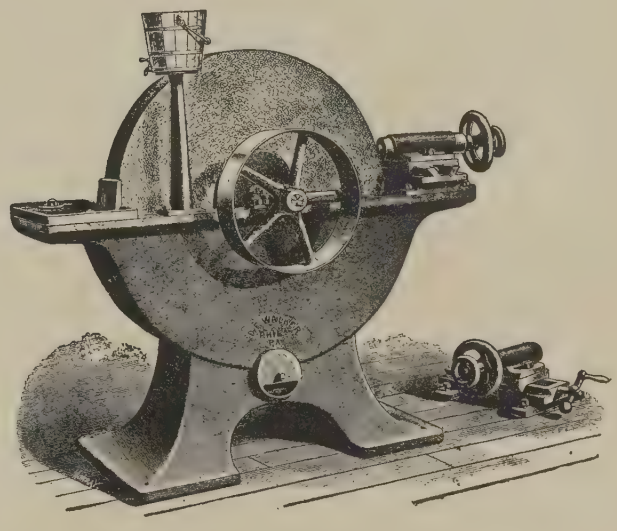


FIG. 514.—GRINDSTONE.

dividual parts in their continuous passage through the mill without having to be carried back and forth several times, resulting in unnecessary steps and consequent loss of time.

In planning a repair shop provision should be made for handling longer timbers than those required for car construction proper; for it not infrequently happens that larger timbers, such as are required in the buildings, bridges or tracks find their way into the wood shop.

Due regard should also be had to the safety and convenience of the operators by placing of the shafting, pulleys, belts and shifters in proper positions and housing them in. The best practice favors placing the shafting beneath the floor, openings being provided for leading the belts to each machine. Regard for the comfort and health of the men employed in this department, and for economy, requires that a system of exhaust pipes and conveyors be provided, with hoods over each machine for removing the dust and shavings and delivering them to the boiler room for fuel. A spiral separator placed at the terminal of the main flue will separate the dust and deliver the shavings in proper condition for the furnace. The exhaust may be produced by a fan operated at or near the engine room. For large shops small trucks and tracks should be provided for the speedy transfer of small pieces about the works.

The number and character of the machines that may be employed to advantage in this department depends upon the amount of work to be done. For repairs alone a very few will answer, but if a company builds its own cars it should have quite a number of the same patterns as are employed in commercial street car work.

The following are among the best machines in the market, and have been selected from the lists of a number of manufactories (Figs. 478 to 514). New machines are constantly appearing, and any car builder who may require a special machine for shaping any piece, no matter how irregular, has but to apply to the makers of this class of tools and the desired device will be forthcoming.

PARTIAL LIST OF WOOD WORKING TOOLS.

A circular re-saw or band re-saw.
Automatic cut-off machine.
Self feed rip saw.
A swing saw.
A four sided planing machine.
A thirty-six inch and a forty-two inch band saw.
A small, one sided pony planer.
An Universal wood worker.
A seven inch outside moulding machine.
A blind slat planer.
A single spindle horizontal boring machine.
A double spindle horizontal boring machine.
A panel raising machine.
A heavy end tenoning machine with double heads and copes.
An automatic hollow chisel mortising machine.
A blind stile mortiser and borer.
A buzz planer.
A complete sash, door and blind relishing and mortising machine.
A sanding machine.
A wood turning lathe, medium size.
A belt sander.
A scraping machine.
A planer for squaring up timber out of wind.
A fret saw.
A band saw filing machine.
A band saw setting machine.
A band saw brazing machine.
An automatic knife grinder for planer knives.
An emery tool grinder.

Fig. 303, page 160, illustrates the position in which the various tools may be placed in a large repair shop to insure economic service. The same figure also illustrates a good arrangement of transfer tracks and turntables, and also the relative position of the different departments.

ERECTING SHOP.

In large works this department often occupies a building by itself; sometimes it is located above the wood working department. In this case, elevators of sufficient capacity for transporting material will also be found to be convenient. As before stated, this department should be carefully parti-

tioned off to protect it from the dust of the machinery department. The temperature should be maintained at about sixty degrees to insure accurate fitting of joints, and lessen the liability of shrinking after being put in service. Carpenters' benches, chests and closets for tools should be provided, and also a system of suspended platforms to facilitate work upon the sides and roof of the car body. Numerous small trucks (Figs. 413 and 414) and horses, before referred to, are a part of the necessary equipment of the erecting shop, for they facilitate the movement of the body as the work progresses. A store room should be provided as an adjunct of this department where all finished parts can be delivered as they come from the wood working department, and stored until they are needed by the body frame builders.

CABINET SHOP.

This department may be provided for in connection with the erecting shop, or the work may be done in rooms set off from the wood working department. But few separate machines are required for this work as the material is usually prepared in the wood working department and delivered ready for fitting. Screw clamps and tables should be provided (Fig. 513), and there should also be provision for storing glass and glazing the sash. Wood mouldings with felt linings are now generally employed instead of putty for holding the glass in the frame; hence, this work properly belongs to this department.

PAINT SHOP.

This is one of the most important departments in car building and should receive careful attention. Besides being located in a convenient position to receive the bodies as they come from the builders, the rooms occupied by this department must necessarily be carefully partitioned to exclude dust and insects, and should be high, having at least fifteen feet between joints, with provision for abundant light on all sides. Light is not only necessary for doing good work, but it also hastens the drying and hardening of paint and varnish. Heating facilities should also be provided, so that a uniform temperature of at least seventy-five degrees can be maintained in winter. This high temperature is not required for the comfort of the workmen alone, but upon it depends the facility with which the paint and varnish can be laid, the depth to which it will penetrate the wood, and, not a little, the durability of the coat. Separate rooms should be provided for the different stages of work, especially in which to finish the cabinet work and veneers. The varnish room should be amply provided with tables, and with racks and frames for holding the spindles, sashes, headings, doors and panels in a horizontal position while the varnish is drying, so that a heavy coat can be laid on without danger of flowing. When dry, these parts may be stored in any position. When it was customary for painters to mix their own colors, the tops of painting tables consisted of a heavy flat stone; now that colors are purchased ready for use the stone is not necessary, and board tops are provided. It is convenient, however, in this connection, to have pieces of thick glass on which to place the colors.

The rubbing room is usually set off by itself, and equipped with benches, washing vats and other appliances, where, by means of pumice stone or rubbing bricks, the wood work is carefully polished and prepared for receiving its coat of varnish.

A store room for paints is a necessary adjunct of this department, from which the material should be dealt out to various workmen upon requisition from the head painter, as is required in other departments.

IRON SHOPS.

Under this head are embraced three departments, the foundry, blacksmith and machine shops, all which should be located near each other. The former is not an absolute necessity in all car building establishments as castings may be purchased or contracted for from commercial foundries. In case, however, such a department forms part of a plant, it should be equipped with the necessary appliances, including one or more cupolas with service elevators and blast fans, also trucks, ladles, sand pits, rumblers, cranes, flasks, core ovens and, if wheels are to be cast, with contracting chills, annealing ovens and wheel grinders (Figs. 460 and 515).

A Pattern Shop and store room for patterns are necessary adjuncts of the foundry. The former should be provided with wood lathes (Fig. 506), band saws (Fig. 496) and other machines necessary for this work, and the latter with racks and shelves, properly numbered and so arranged that any pattern may be readily found when required. Good light and proper ventilation should not be overlooked in planning buildings for the foundry department.

The Blacksmith Shop requires for its equipment forges, anvils and, if the work is to be heavy, one or more steam hammers (Fig. 516), bending machines (Fig. 519), etc. To facilitate the removal of the smoke and foul gases from the forges, a flue with mechanical exhaust should communicate with each, and each should be served with an air blast for forcing the fires. Power cranes, trolley cranes and hand hoists, to facilitate the handling of heavy material, should in all cases be provided. The iron store room, with proper racks for storing the bar iron and steel, is usually located adjacent to the blacksmith shop, and here the power shears (Fig. 527) and punches (Fig. 517) for cutting the bars and plates to proper shape are also placed. Weighing scales, hand barrows and trucks complete the equipment of this department.

A Machine Shop, with a more or less elaborate equipment of iron working tools, is a necessary department in any car building or repair works. If for repairs only, both the blacksmith shop and machine shop may be located so as to flank the reception and pit tracks, from which they may be readily served with the parts needing repairs by overhead trolley tracks, with switches and crossings so located that communication can be had with every department. The overhead trolley and hand lifts may be employed instead of jacks for lifting car bodies and removing motors. (See last chapter.)

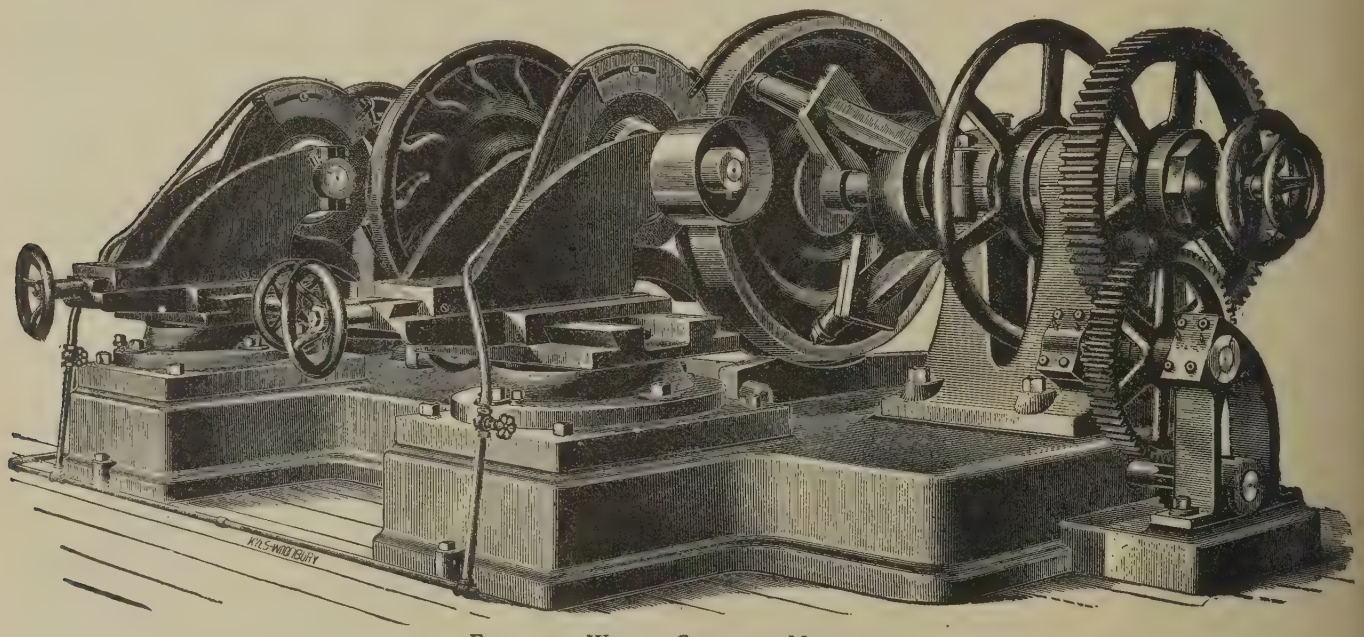


FIG. 515.—WHEEL GRINDING MACHINE.

The following are among the most important iron working tools that will be required for commercial car building or for making repairs. These are manufactured in various sizes and may be duplicated according to the amount of work to be done; axle lathe, engine lathe, radial drill, drill press, planer, key seating mill, slotting machine, wheel boring mill, wheel press, journal box grinder and steam hammer. Some of these are illustrated in the accompanying engravings (Figs. 518 to 529).

A portion of the machine shop is usually partitioned off for the grinding room, where are located the stones and emery grinders for polishing and finishing the close fitting or ornamental parts which enter into car or truck construction. Sometimes a

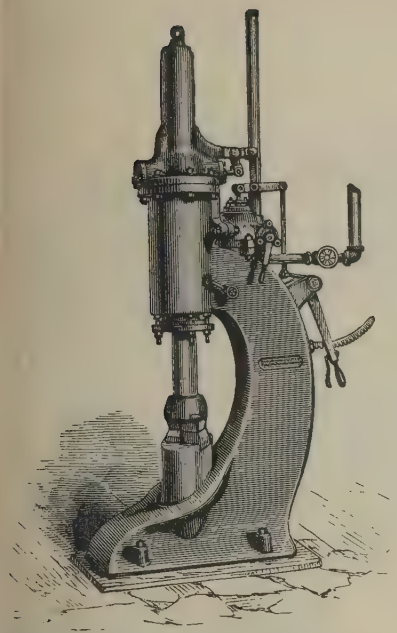


FIG. 516.—SELLERS STEAM HAMMER.

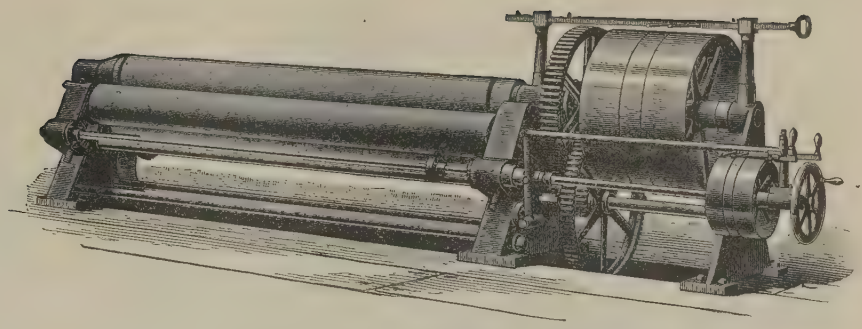


FIG. 519.—PLATE BENDING MACHINE.

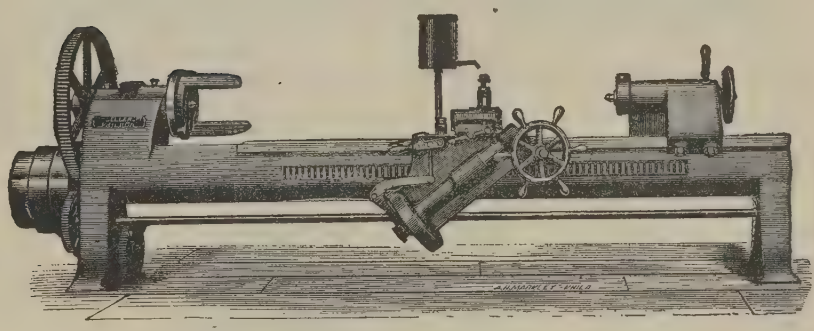


FIG. 520.—SINGLE AXLE LATHE.

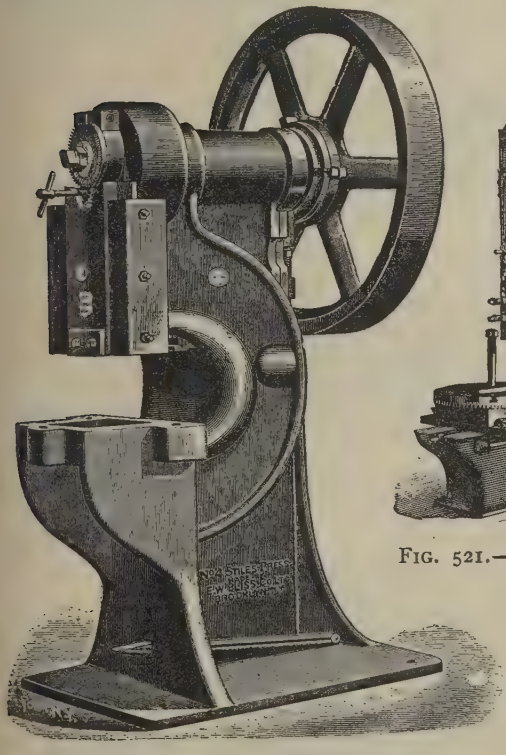


FIG. 517.—POWER PUNCH.

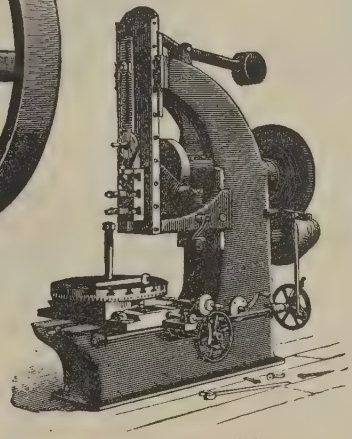


FIG. 521.—SLOTTING MACHINE.

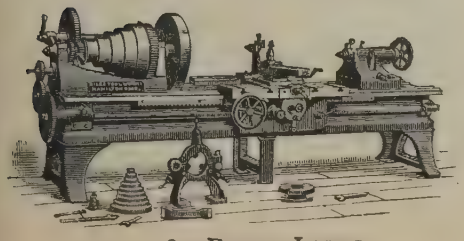


FIG. 518.—ENGINE LATHE.

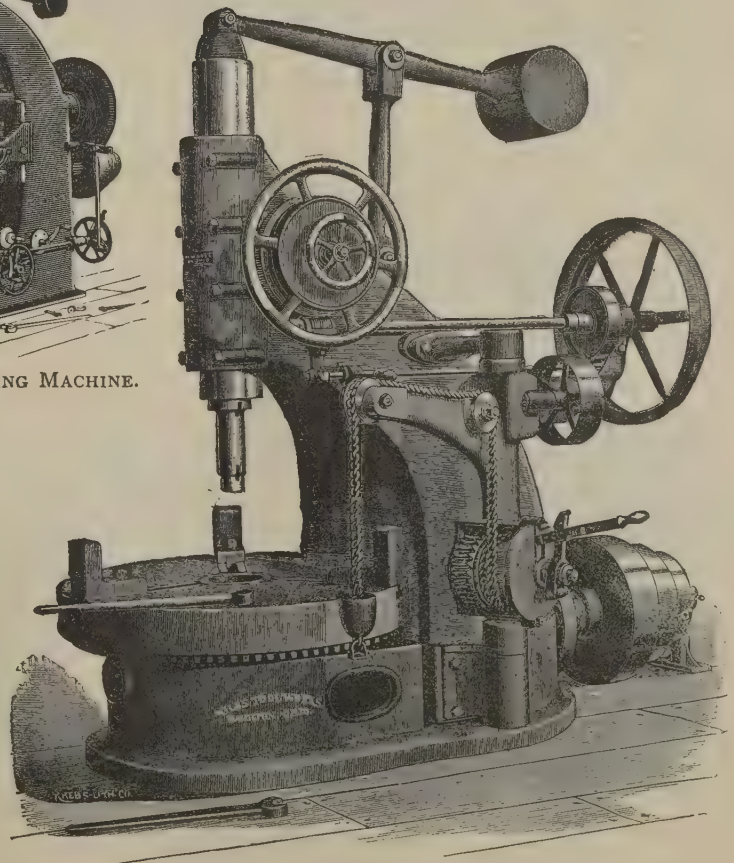


FIG. 522.—CAR WHEEL BORING MACHINE.

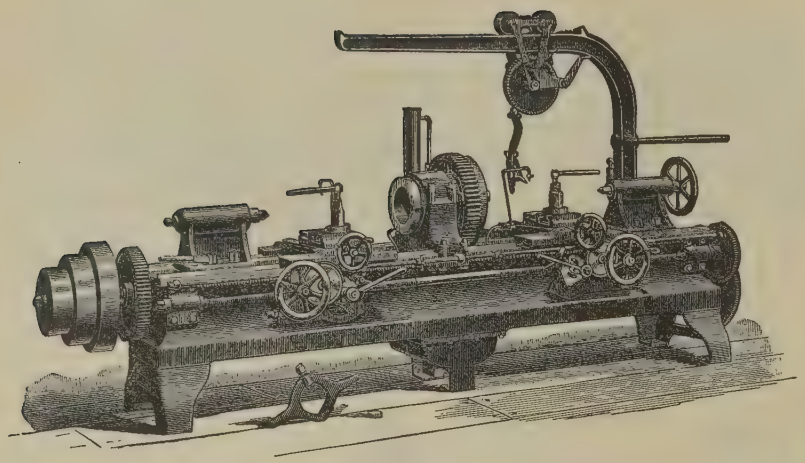


FIG. 523.—DOUBLE AXLE LATHE.

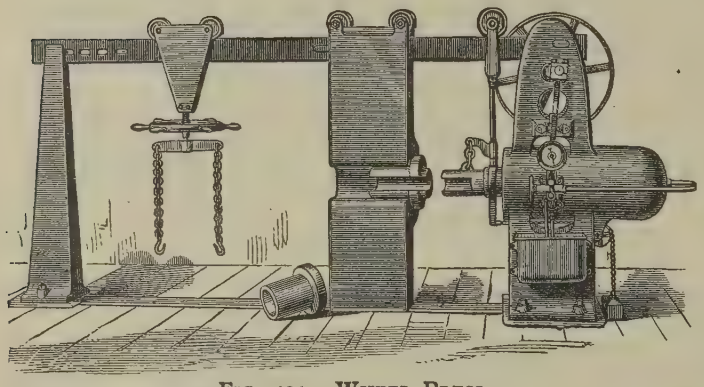


FIG. 524.—WHEEL PRESS.

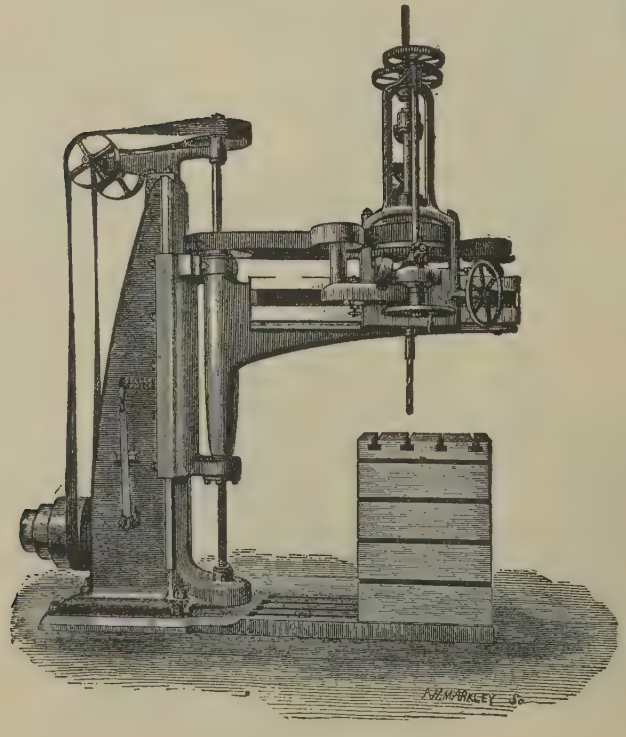


FIG. 525.—RADIAL DRILL.

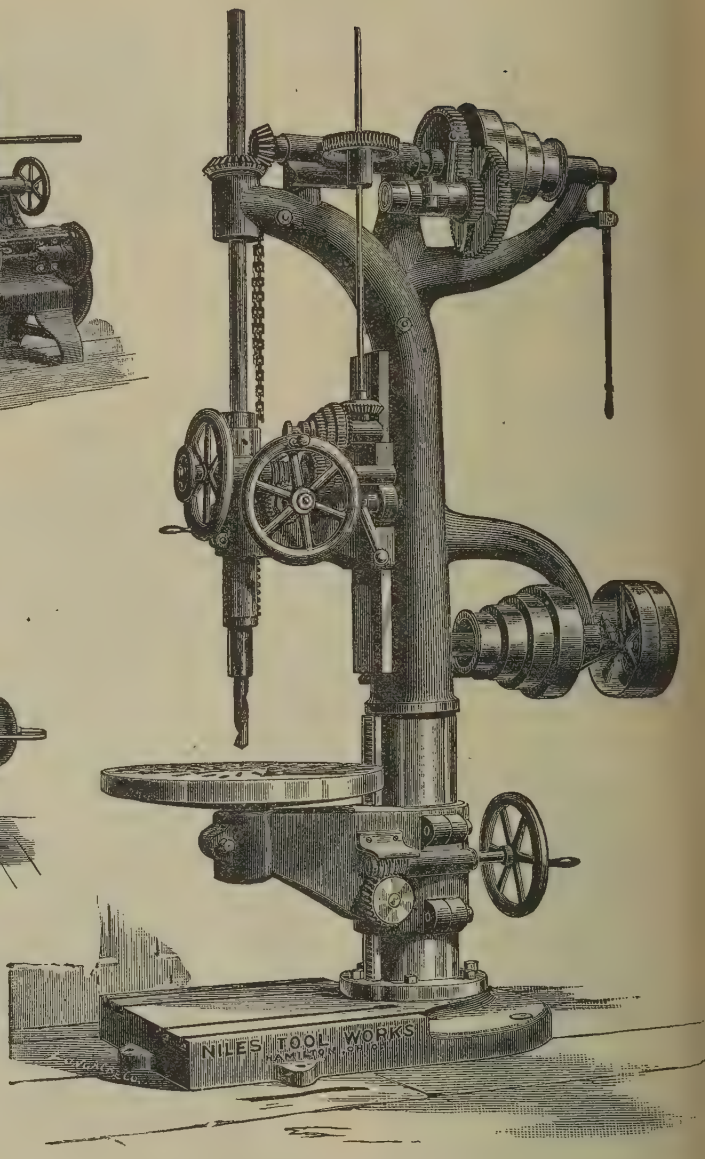


FIG. 526.—VERTICAL DRILL.

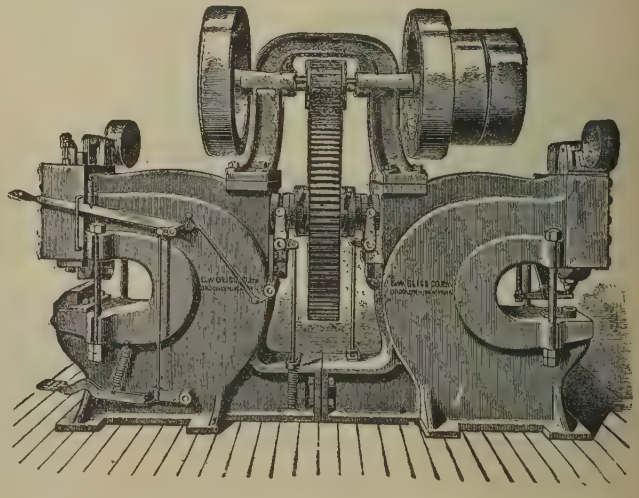


FIG. 527.—POWER SHEARS.

separate building is employed for the truck erecting shop; for this only a few tools are required, but the overhead lifting arrangements should be ample.

The Tin Shop, by no means the least important feature of a car building works, is usually located in the vicinity of the iron tool shop and may occupy a room on any floor. In this department are prepared the lamp flues, stove pipes, stove box lining, ventilating jacks, thimbles and plates for roof work. Also lamp-oil cans, waste cans, water tanks, etc. The tools required embrace all the appliances found in ordinary tin or stove shops.

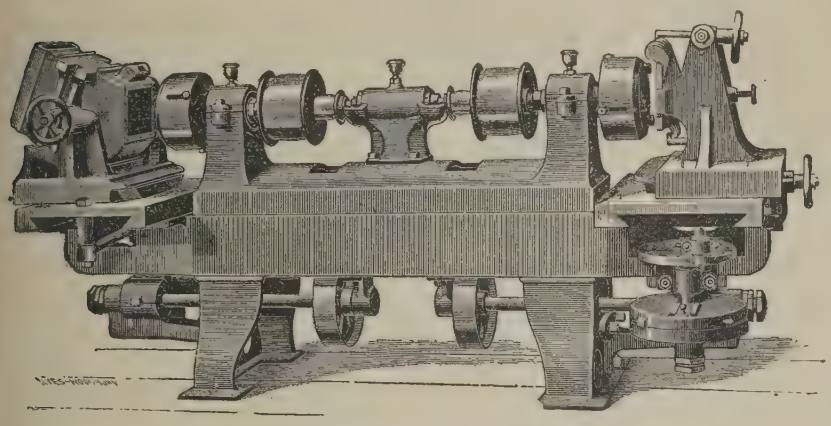


FIG. 528.—JOURNAL BOX GRINDER.

SHIPPING.

It is frequently necessary to ship cars that have been built for the trade over long distances, either by rail or by water, in which case they must be boxed or otherwise protected to prevent their being injured *en route*. The bodies may be shipped already mounted, or bodies and trucks may be shipped separately. When dismounted false sills are sometimes placed under, to which the body is securely bolted. These sills provide for the use of rollers, which facilitate the work of shifting the body about. All bronze rails should be carefully wrapped with burlap. In case boxing is not required, most builders provide canvas or waterproof covers which enclose the entire body, and may bear the imprint of the manufacturing firm. These covers being returned often do long service and answer for various shipments.

Some companies own their own shipping cars which are usually of the platform type and of sufficient length (fifty or sixty feet) to accommodate two ordinary bodies, upon which they are transported over the different steam lines to their destination. Frequently, these shipping cars are provided with a housing of sufficient capacity to enclose and protect the largest street car body.

For export trade it is sometimes necessary to so construct the body that it can be knocked down after being finished and compactly packed for shipping. In this case the sides, ends, roof, hoods, platforms and bottom are so connected that by removing a few bolts each may be separated from the other parts, and after reaching their destination can be readily set up and securely united.

In case a car building establishment is not located near a steam line, it is customary to provide low platform wagons, on which the car can be transferred from the shop to the shipping station. These platforms, being equipped with grooved or adjustable rails, provide for handling trucks of any gauge.

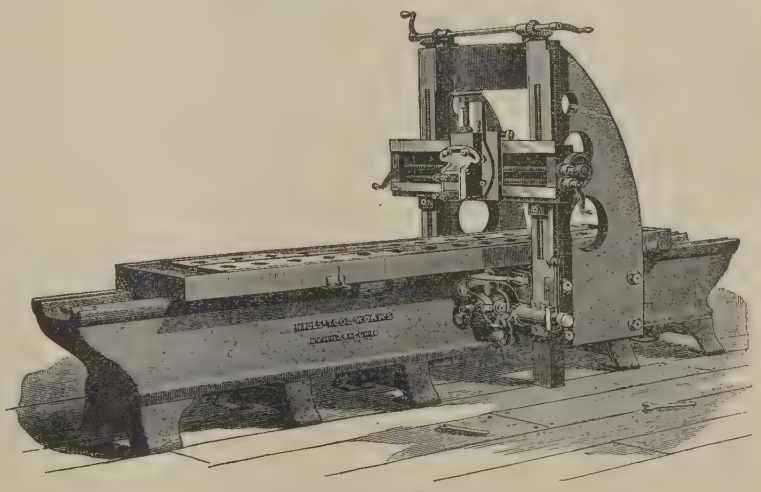


FIG. 529.—IRON PLANER.

CHAPTER IX

TRACK CONSTRUCTION.

A prime requisite in all street railway operations is permanency, and in the long chapter of expense items that inevitably accompany mechanical traction a large percentage (as high as fifteen on some electric lines) is due directly or indirectly to defects in the tracks, particularly at the joint connections. Hence, it is desirable to reduce this percentage to the smallest possible limit, and roads that are designed to do a large amount of business must advance their tracks to such a condition as will allow of cars being run on short headway and at a high rate of speed, or they will imperil their very existence by defects inherent in the permanent way.

Among the many depraved traits that inanimate matter possesses, none have caused greater surprise or reflected more severely on the skill of engineers than the behavior of rails and joints since they were made to do service under electric cars, and notwithstanding that a great amount of inventive genius and experimental effort have been expended in improving the details of foundations, ties, rails, and joints, street railway companies everywhere feel more or less solicitude lest they fail to secure the highest standard of excellence desired.

Although no construction with which we are acquainted meets all requirements in a fully satisfactory manner under all conditions, great advances have been made, and this line of engineering, which heretofore has been considered a humble branch of the profession, is now receiving the attention of the best engineering talent of the country, and some of the modern arrangements represent notable and important improvements over former practice; still, the possibilities of improvements are not yet exhausted, and when more practical knowledge shall have been acquired and disseminated, and engineers discover by failures what not to do, track construction will doubtless be advanced to a more creditable condition, but it cannot be expected, in spite of all that will be done, that incessant labor will not be necessary to keep the best of construction in first class condition.

Were it not that the significance of the above points is frequently ignored by street railway companies, an apology should be made for presenting them; but some street railways have been built for sale rather than for use, and others, on account of lack of funds, are sometimes constructed in a manner known to be imperfect, in the hope and expectation that they will gradually be improved after earning power is attained. Such expectations will never be realized in electric traction. Although it is possible with horse traction for cars to be operated with little danger for long periods over defective tracks, it is not so with the new power, for any defects in the joints, which are usually the weakest places in the track rapidly grow worse, so that not only are the rails worn, but much greater damage is inflicted upon the trucks and car appliances. The problem, from a street railway point of view, not easy of solution, is usually further complicated with conditions named in the franchise, which relate to paving, rail sections and care of tracks.

In treating the subject it is necessary to consider the preparation of the foundation on which the tracks are to be laid, the selection and adjustment of ties or their equivalent, the fastening of rails to ties, the type of rail, the connections between rails, the proper laying of rails on curves, the construction of turn-outs, frogs, switches, crossings and paving.

SURVEY.

In case a new line is to be constructed, a survey of the route is first necessary, but this requires some knowledge of elementary geometry and other mathematical sciences, and great care is necessary in taking the measurements, recording the data and general conditions; hence, this work is usually del-

egated to specialists in this line, and since it is a custom with rail makers to employ men well versed in this work who make all necessary surveys and estimates free of charge to parties ordering a rail equipment, it is not essential that the details of the work be treated in this connection. It is important, however, that the street railway companies for whom the work is being done direct that spiral transition curves be employed in laying out the work for turns, in order to lessen the danger of derailment and reduce the strain and shock to cars and motors, which, with mechanically propelled cars, is very great on circular curves. In case, however, one wishes to study this subject, a pamphlet entitled "The Railroad Spiral," by Searles, will give the desired information.

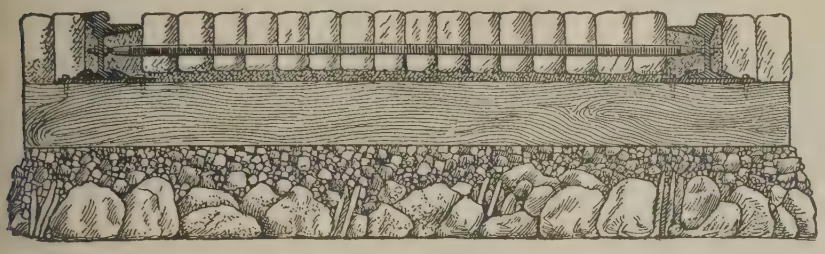


FIG. 530.—CROSS SECTION OF TRACK ON BALLAST FOUNDATION—GIRDER RAIL SPIKED TO TIES.

FOUNDATION.

In no class of roads is it so essential that there should be a thoroughly good road bed as with electric lines. In the absence of a proper foundation it is useless to expect good results from the superstructure, no matter what the type or weight of rail may be. Differences of opinion formerly prevailed in regard to this matter, but positive conclusions have now been reached, and these are that it is just as essential as in steam practice to have a ballast of clean broken stone, gravel or furnace slag, at least a foot deep under the ties, with the space between the ties filled up evenly to the top, and provided with tile drains at proper intervals to remove any excess of moisture that may percolate through the pavement. In placing the ballast, coarse, large stones, set edgeways, may be placed at the bottom in order to provide for drainage, but care should be taken to keep the coarse stone from coming up to the bottom of the ties, as these should rest only on gravel or finely broken stone thoroughly rolled or tamped (Fig. 530). Those who have experienced trouble from the paving blocks being forced from their beds by the churning action of the ties, accompanied by a flow of soft mud, will appreciate the importance of the above drainage requirements. In some cases proper ballast has been provided, but provisions for drainage being neglected, unsatisfactory results followed, as is likely to be the case, especially where the formation is of clay; hence, the suggestions for drainage are emphasized. Fig. 531 illustrates one method of ballasting employed on the steam lines of the Pennsylvania Railway. (The term "ballast" is applied to material employed in this manner, because stones that had been used for ship ballast were first used for this purpose on steam lines near Newcastle, England.)

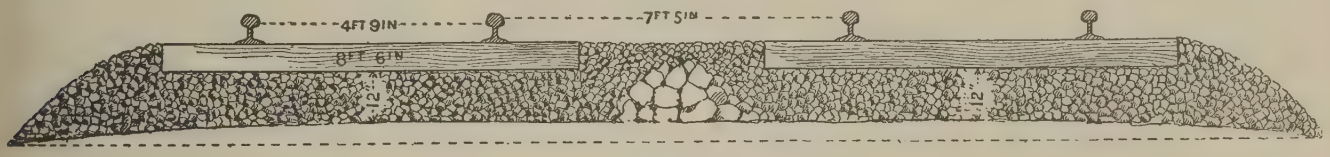


FIG. 531.—CROSS SECTION OF STEAM RAILWAY CONSTRUCTION WITH STONE BALLAST.

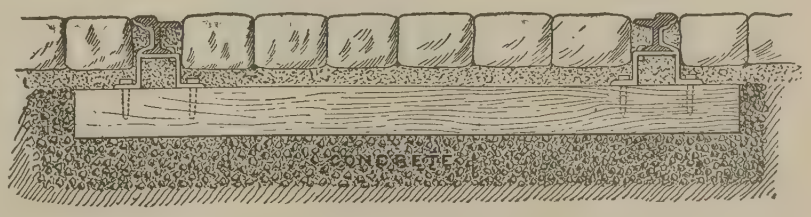


FIG. 532.—CROSS SECTION, GIRDER RAIL ON CONCRETE FOUNDATION.

Another important factor in securing an enduring road bed is the track laborer, and special attention should be given to the selecting and drilling of the men emlpoyed and to impressing upon them the

importance of *thorough and conscientious track work*, especially in tamping, for much defective track is due to careless and insufficient tamping. In some sections it may be difficult to secure the services of men who are willing and competent to perform this part in a reasonably correct and efficient manner, but the importance of strict thoroughness should be understood by the contractors and section foremen at least.

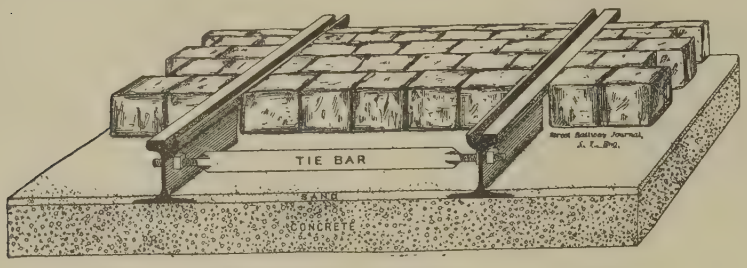


FIG. 533.—BIRMINGHAM TRAMWAY CONSTRUCTION.

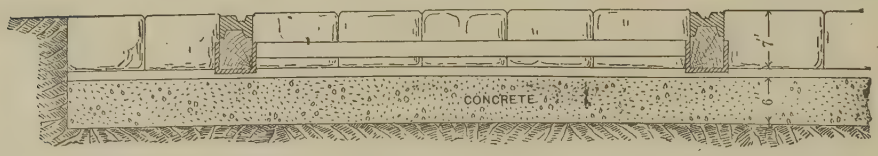


FIG. 534.—DUNEDIN TRAMWAYS.

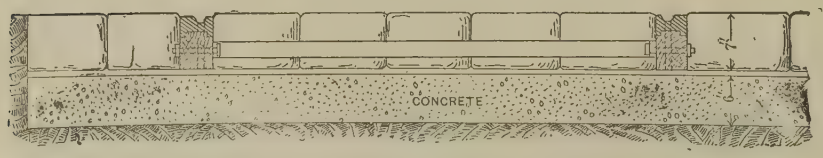


FIG. 535.—EDINBURGH TRAMWAYS.

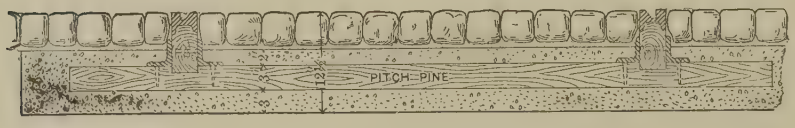


FIG. 536.—SOUTHPORT TRAMWAYS.

We are aware that a foundation of concrete has been provided on some lines in place of stone ballast, and that in a few instances a creditable service has been secured (Fig. 535), but disastrous results have usually followed the use of concrete in this form or as pedestals under joint chairs. Especially will it be found imprudent to lay concrete on soft or newly made road bottoms. These remarks refer to electric lines. Concrete foundations have been quite generally employed on foreign lines using animal power, and in most cases have proved quite durable, but there are many conditions that militate against such construction in this country. Some of these are the climate, the condition and care of streets, first cost, paving requirements, etc. Figs. 533 to 540 illustrate present and former English practice in this respect and show the different methods of fastening rails.

TIES.

Metal ties have been employed in electric service, to a limited extent, in place of wood, with a view of securing an imperishable foundation, and considerable inventive effort has been expended in this direction, but no very satisfactory results have been obtained, so far as we are informed. There is also a system designed to obviate the use of ties which employs broad based

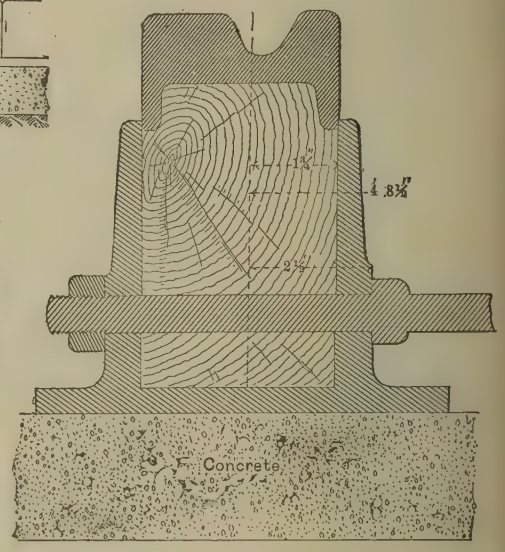
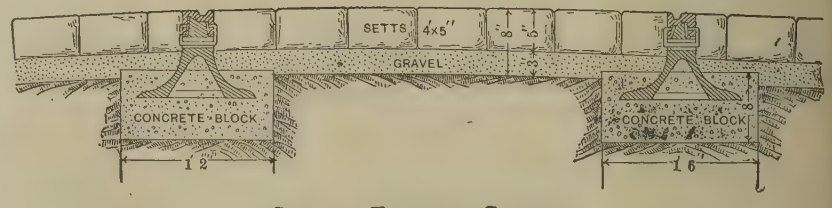


FIG. 536A.—SOUTHPORT TRAMWAYS.



SECTION THROUGH CHAIRS.

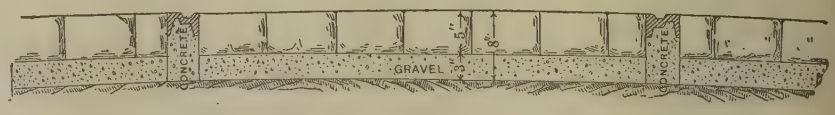


FIG. 537.—BRISTOL TRAMWAYS—SECTION BETWEEN CHAIRS.

metal chairs in their place; of this we will speak later on. In the meantime, when ties are necessarily employed, their selection and adjustment will be governed somewhat by the kind and price of material in local markets. A number of varieties of wood are used, and different methods of preparing it are adopted, some being sawed, others hewn; the latter are generally considered best, for the rounded edges allow of thorough tamping, but in all cases the bark should be removed before the ties are placed on the foundation. Yellow pine is generally considered best for ties, but adverse elemental forces frequently bar the use of certain woods in some localities, in which case it is necessary to be governed by experience had on old lines. The dimensions of ties for electric lines should be 5 ins. × 7 ins., or better, 6 ins. × 8 ins., and they should be seven feet long for standard gauge, and not less than sixteen should be used for each thirty foot rail. The spacing at the joints may be determined by the width of the ties employed, as shown in Figs. 541 and 542, but the type of rail will govern the spacing of ties somewhat. In case the rails are

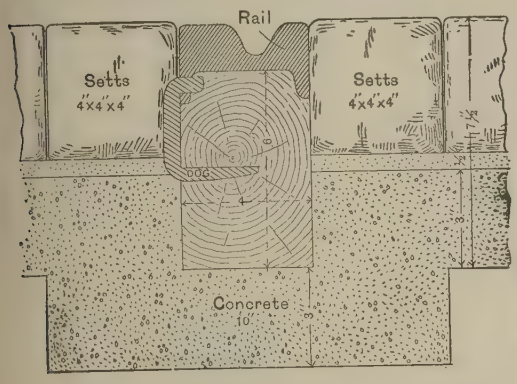


FIG. 538.—MANCHESTER TRAMWAYS.

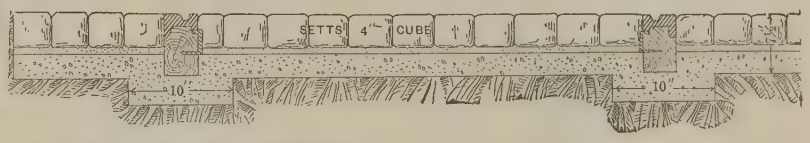


FIG. 539.—WIRRALL TRAMWAYS.

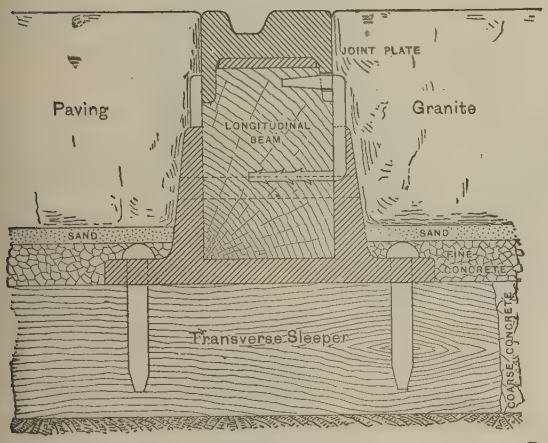
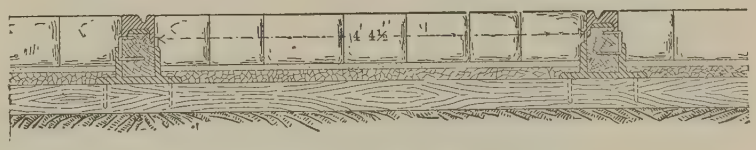
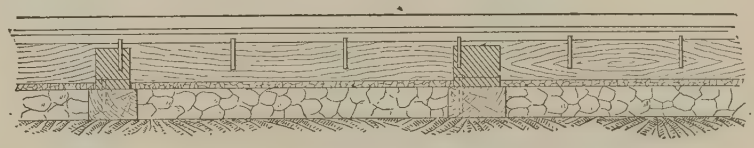


FIG. 540. GLASGOW TRAMWAYS.



CROSS SECTION.



LONGITUDINAL SECTION.

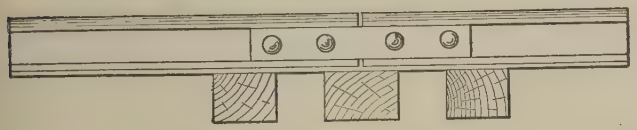


FIG. 541.—THREE TIE JOINT.

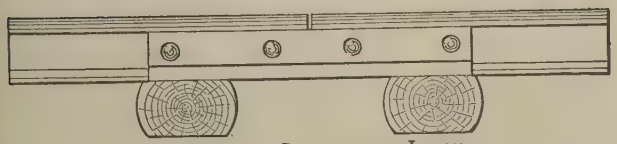


FIG. 542.—SUSPENDED JOINT.

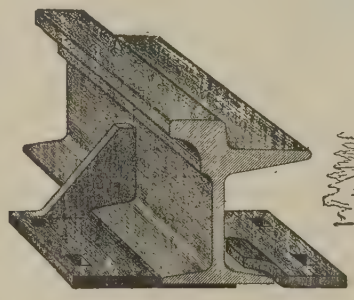


FIG. 544.—BRACE TIE PLATE.

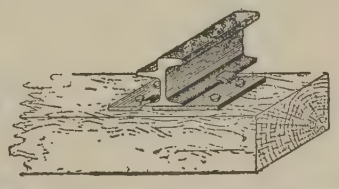


FIG. 543.—STEEL TIE PLATE.

spiked directly to the ties, the use of a Servis tie plate (Fig. 390), or the ordinary steel tie plate is recommended (Fig. 543), as they prevent the cutting of the rail into the tie.

RAIL FASTENINGS.

The method of fastening rails to ties will, in many cases, be governed by the local requirements in regard to paving. The best results, by far, are obtained where the rail, be it a Tee or girder type is spiked directly to the ties. In locations where low wooden blocks, vitrified brick or asphalt are employed as paving material, rails of the ordinary results have been secured in some localities by the employment of a longitudinal stringer on which a girder rail of the ordinary depth is placed (Fig. 548.) In case the stringer is employed, care should be exercised in selecting the kind of wood that is known to be the best to resist decay in any particular soil or climate as in the case of ties, and the stringers should be cut in as long and uniform lengths as possible. The stringer may be secured to the ties by means of cast knees, as shown in the figure. While this construction has given reasonable satisfaction in paved streets having a

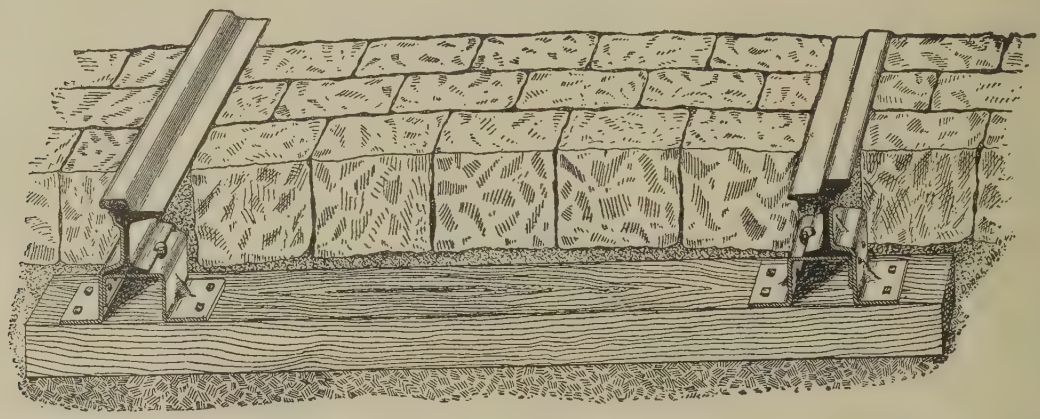


Fig. 545.—Cross Section Street Construction, Girder Rail, Wrought Brace Chair, Marshall Clips.

height, of four and a half or five inches, may be thus secured. In case the pavement is to consist of granite sets of ordinary depth, it will be necessary to support the rail upon chairs or wooden stringers, or employ a specially designed rail of sufficient depth to allow it to rest directly upon the ties. In case chairs are used with girder construction (Figs. 545, 546 and 547), those of wrought metal are preferable to those of cast iron, as the latter, unless they are very heavy and strong, are apt to break, especially in cold climates. It is also of advantage to have the rail and chairs united by electric welding. Both from a street railway point of view and that of the local authorities, the employment of chairs resting on cross ties for supporting the ordinary types of rails on electric lines is undesirable, as it will be difficult to keep the rail in position, and a frequent disturbing of the pavement will be necessary. As a substitute for chairs good moist soil, it has not proved to be desirable in unpaved streets where the soil is sandy.

It is proposed in certain localities to employ a girder rail having a broad base and of sufficient total height (nine or ten inches) to allow of its being spiked directly to the ties, and yet provide space for the paving blocks and gravel bed above them. This, theoretically, is an ideal construction with girder rail, but it remains for service to demonstrate if the first cost and increased surface wear, because of the increased stiffness, are not prohibitory.

Attention should be given to the type of spike employed for rail and chair fastening, and the metal from which they are made. For fastening the rail directly to the tie or stringer, railroad hook spikes of soft steel, not less than four and a half inches long, are recommended. Those having specially designed points (Fig. 549) are preferable, as they cut the fibre of the wood better than the

chisel pointed spikes and have better holding qualities. Double headed spikes (Fig. 550) may be employed to advantage for fastening chairs and tie plates, for when driven there is sufficient space left between the plate and second head to readily admit the claw bar when it is necessary to draw the spike, so that the head is not as liable to come off as is the case with the common spike.

THE RAIL.

Service has demonstrated beyond question, thus far in the history of electric traction, that the Tee type of rail, when of proper dimensions, and spiked directly to the ties, has given the best satisfaction from the operator's point of view wherever its use has been allowed. Hence, for suburban lines, and lines operating on paved streets in small cities, the use of the Tee rail is recommended. It may be questioned, however, if its use on paved streets, where there is a good deal of vehicular traffic is economical, on account of the rapid wearing out of the pavement next the rails. When this rail is laid in streets paved with wood or stone blocks, it is necessary to chamfer off the corners of the blocks next the gauge side of the rails to provide a channel for the wheel flange. Some of the claims made for this type of rail are its vertical and lateral stiffness, durability, ease of draught and small first cost. When used it should be modelled after the designs employed on the leading steam roads, one of which is illustrated in Fig. 553. which shows the standard rail and connections at present employed on the Pennsylvania lines; but should this type be employed for electric service, the nearer it is copied in weight as well as design, the more satisfactory will be the results, provided the joint connections receive proper attention.

FIG. 546.—CLIP TIE CHAIR.

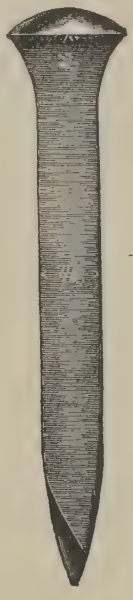


FIG. 549.
SPECIAL POINT CHAIR SPIKE.

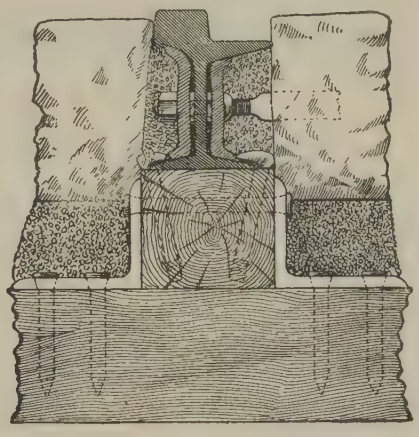


FIG. 548.—GIRDER RAIL WITH STRINGER SUPPORT.

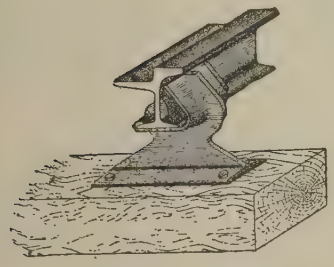


FIG. 547.—ROLLED STEEL CHAIR.

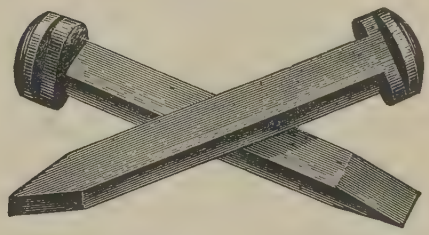


FIG. 550.—DOUBLE HEADED SPIKES.

The use of the Tee rail, however, is necessarily confined to a limited field in street railway service, owing to local requirements and conditions, so that for the larger service, unless a new type should be developed, some form of the girder rail must be employed, on mechanically operated lines at least.

From the shape of the head, girder rails may be divided into three kinds, designated centre bearing, side bearing and grooved (Figs. 552, 553 and 554.) Each of these forms may be rolled with or without a base flange, or the web may terminate in

a bulb. Only those having a wide base, however, are suitable for electric traction. There are other forms designated by variations in the web ; one is known as the double web or box rail (Fig. 555);

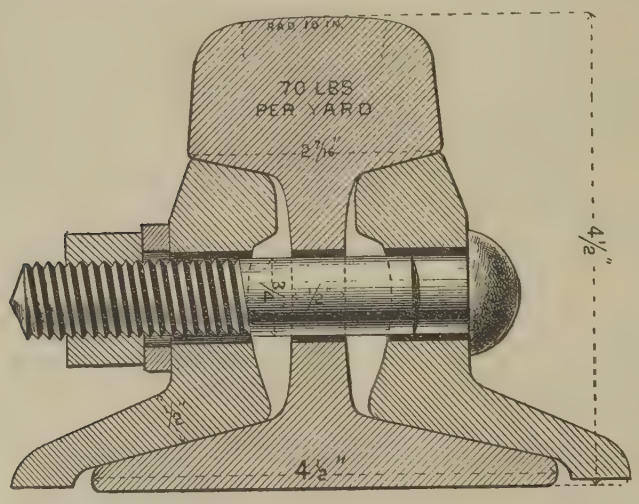


Fig. 551.—Tee Rail—Pennsylvania Standard of 1889.

another as a double girder or duplex rail (Fig. 557), which is rolled in two parts, with the head and tram each provided with a web and designed to be laid with broken joints, or so that each part in turn solidly underlaps or overlaps the joint connection of the other. These rails take any head outline desired, and require no base flange.

In reference to the form of the head, the centre bearing rail is the most desirable from the operator's standpoint ; because, from the shape of the head, it readily sheds dirt and offers less resistance to the wheel than other types, but its use is prohibited in many localities because it is difficult for the wheels of vehicles to mount the head in getting in or out of the track ; hence, it is necessary to employ the side bearing or grooved rail, or a compromise between them, something that will give reasonable satisfaction both to wagon owners and the operating companies.

Exactly the best width of head for a given weight of rail can hardly be determined. A wide head reduces, theoretically, the pressure per square inch of wheels, but on account of the slight coning of the wheels their actual contact is only from one-half to three-fourths of an inch. If the head is wide it must be thin, with a given weight of rail, so that its side presents less surface, with a higher rate of flange wear, and a greater variation in the gauge of the tracks. The heads must be deep enough to allow of a reasonable amount of wear, before the wheel flange will come down upon the tram.

Practice has determined that the best average width of head, for anything above a fifty pound per yard rail, lies between two and two and a half inches, with a depth of one inch or an inch and an eighth at the gauge line. Every possible fraction of the remaining half inch in the width has been adopted, but no one can prove that each is not the best. In any case the head should be so designed that the weight of the wheel will come directly over the web, to prevent any tendency of the rail to cant over, which will be the case if the slightest leverage is given to the weight. In designing rails for animal traction it may be necessary to so place the web that it will bear the weight imposed upon the head as well as that imposed upon the tram from vehicular traffic ; but for electric traction this is seldom necessary, for the car service

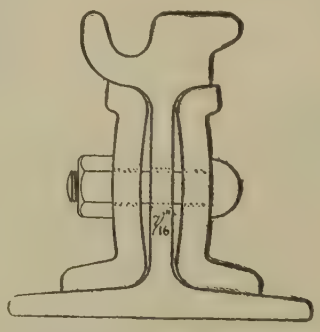


Fig. 554.—Grooved Girder Rail—Washington Type.

Fig. 552.—Centre Bearing Girder Rail.

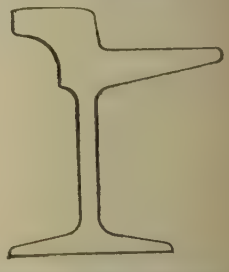


Fig. 553.—Side Bearing Girder Rail.

is first to be provided for ; and since this is usually so much harder than the wagon service the latter may usually be ignored.

The tram or flange of the ordinary girder rail should be so designed that it will last as long as the head. As the part next to the head is the most subject

o wear, it may be thickened at this point and allowd to taper away to the extreme point in order to conomize in weight. The flange of the rail under lectric traction is not liable to wear out before he head, as is the case with animal traction, unless he street traffic should be extremely heavy ; hence, ot so much attention should be given to its design as formerly, except in the direction of width. In egard to the width, most companies will be governed by local requirements, and if they must provide for wagon travel the tram should be as narrow as the requirements will allow (as narrow as two inches if possible), both to reduce the tendency of the rail to cant inwards, by reducing the leverage, and to add to its paving qualities. The latter is an important consideration, for if the tram is very wide the adjoining paving blocks, when they settle, are apt to cant under the tram, making a dangerous trap for horses' feet. This tendency, however, can be provided for to a certain extent by filling the pocket of the rail under the tram with concrete or specially designed vitrified brick, before the paving blocks are put in place.

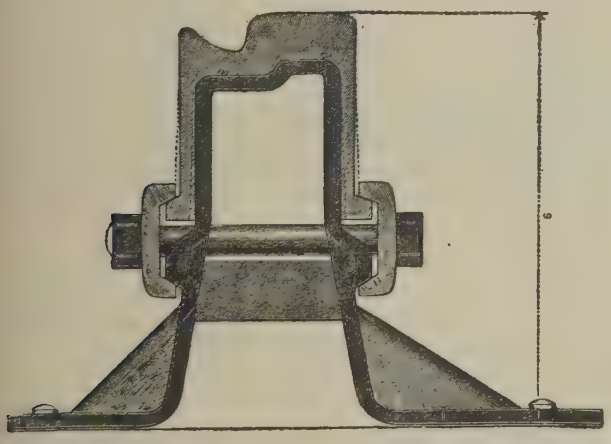


FIG. 555.—BOX GIRDER RAIL.

The web of the ordinary girder rail is usually pared down to from one-fourth to seven-sixteenths of an inch. So far, no web of any of the leading patterns has broken down from being too thin. Any variation from the above is of little importance, for no one can say whether a sixty-fourth should be added or removed unless an unusually high (ten inch) rail is to be employed, when a bead may be added along the centre of the web on each side. The height of the web, however, is quite important ; and were it not for paving conditions it would be easy to perfect the rail as a beam and establish a standard height for given weight because the stiffness of a beam increases as the cube of the height ; and it has been found in steam practice that a well proportioned rail of about four and a half inches in height will carry loads of five or six tons per wheel to the best advantage. But it has also been ascertained that rails only half an inch higher wear out more rapidly on the surface than the lower rails of the same quality. This is explained by the fact that the higher rails, being more rigid, decrease the time of impact of the hammer blow of the wheel (whose destructive effect is as the square of its velocity) and so increase the power of the blow. As before stated, it is yet to be determined whether this increased wear, due to increased stiffness, will militate against the employment of a deep rail to obviate the use of chairs or stringers. Of course, where the ties, or yokes in cable lines, are placed quite a distance apart, and it is thought desirable to suspend the joints, a deep rail will, theoretically, carry the load without much deflection out to the end and impose less service upon the joint connections, and the rail, being deep, allows the use of deep connecting plates.

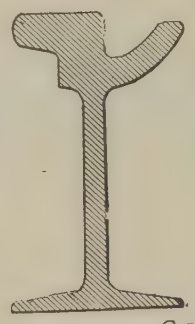


FIG. 556.—GROOVED GIRDER RAIL—NEW YORK TYPE.

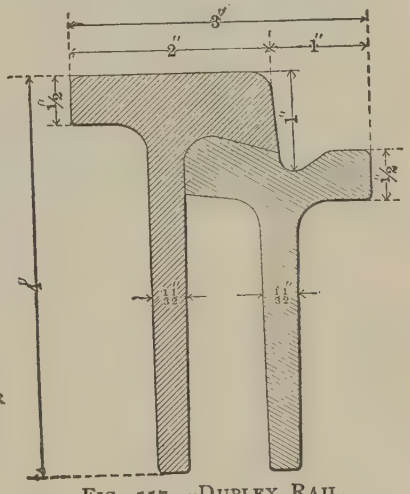


FIG. 557.—DUPLEX RAIL.

The relative advantage of a deep beam, even under these conditions, when the first cost and value of scrap are considered, is a difficult question to de-

termine, as are also the relative merits of a rigid and an elastic construction, and both must be left until new conditions of road bed, load and manufacture

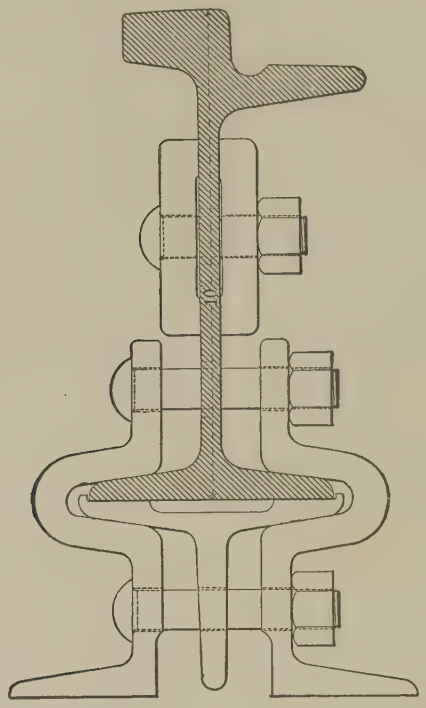


FIG. 558.—PROPOSED HIGH GIRDER RAIL—BOSTON TYPE.

shall have indicated further improvements in the weight and proportion of steel rails for street railway service.

The width of the base of the ordinary girder, which is designed to be spiked directly to the ties, is not so difficult to determine as the height, and the best practice makes the base and the height the same. With a wide base the tendency of the rail to turn over is not so great, and it is not as liable to cut into the tie or stringer. When employed with chairs it should also be wide, and the base of the chairs should be spread to correspond with the total height. The ordinary length of the girder rail is thirty feet, but practice is tending in the direction of a longer (forty-five foot) rail, following the example set by some steam lines. This practice will reduce the number of joint connections, but should the contraction in cold weather all take place in one direction, it would leave too wide a space at the joint.

The grooved girder rail (Fig. 554) was an importation from English practice, and where the conditions are favorable it has given excellent results. Its use, however, is recommended only in mild climates and on streets that are kept scrupulously clean, for the reason that, ordinarily, the groove will become packed with dirt, bits of ice, snow or mud, thus causing the wheel to rest upon its flange, and increasing the resistance and tendency to derail the car. It must be laid to a close gauge; and it is estimated that it requires, ordinarily, from thirty to forty per cent. more power to operate cars upon it than on the side bearing or Tee rail. The flanges of the wheels wear rapidly on both sides, and there are other minor objections to its use, so that it is an imposition on the part of city authorities to require that it be used except where the conditions are favorable, as above noted. It is, no doubt, a desirable rail from the point of view of the public, for it offers little or no obstruction to wagon traffic, as the pavement can be laid flush with the surface on both sides; and where the streets are paved with asphaltum it can be driven over in any direction without its presence in the street being detected. If, however, the pavement is not carefully maintained and is allowed to settle irregularly, the rail becomes exposed, wagon wheels form ruts, and its obstructive features soon exceed those of other

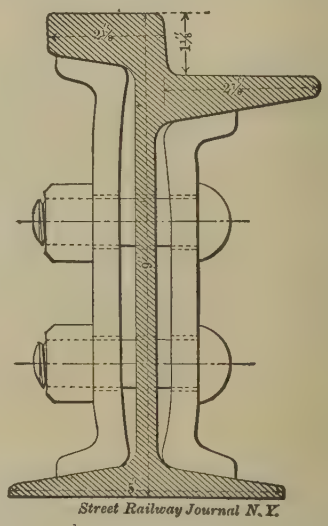


FIG. 559.—HIGH GIRDER RAIL—PHILADELPHIA TYPE.

types. In some cases, where the use of this type of rail has been insisted upon by state or city authorities, a compromise has been effected by forming the groove with an inclined or dishing wall on

ıe inside, or terminatıng the point of the tram a ttle below the level of the head (Figs. 556 and 555. ee also Figs. 173 and 174, p. 83). With this arangement the flange of the wheel tends to cut hrough and crowd the obstructions out of the

Another high rail (Fig. 559), has been designed for use on some of the Philadelphia lines. The illustration shows the method of joint connection, which consists of deep angle plates held in position by two rows of bolts.

FIG. 560.—BOX GIRDER RAIL IN MACADAM PAVEMENT.

groove, and the pavement may be laid flush both with the tram and the head.

Fig. 558 illustrates a high (100 lb.) girder rail before referred to, and which has been designed for use on some of the Boston lines. The engraving shows the rail at the joint, and also a section of

The box or double web girder rail, illustrated in Figs. 555, 560, 561 and 562, has been designed to obviate some of the alleged defects inherent in the ordinary patterns of girder rails. It has great vertical and lateral strength with a minimum amount of metal; excellent paving qualities, in that the

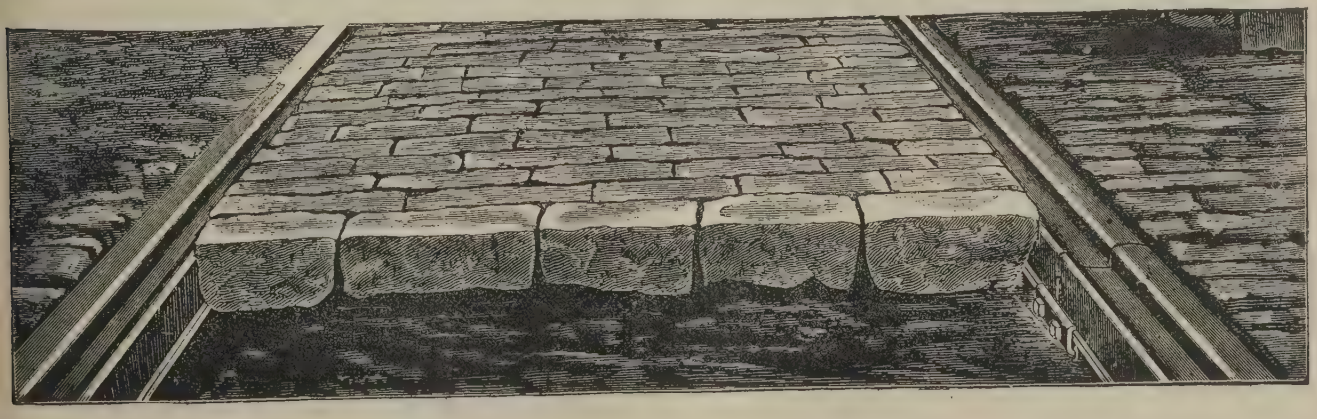


FIG. 561.—BOX GIRDER RAIL IN STONE PAVEMENT.

the girder or "standard" joint which is designed for use with this type of rail. Between the joints the rail is to be spiked directly to the ties, as it is of sufficient height to allow of paving with regulation granite sets without any blocking up.

vertical sides offer ample support to paving blocks and prevent their tilting over even though they settle below the level of the head; facility of adjustment to chairs or ties without any bolt holes through the webs, and admits of em-

ploying long and durable joint connections. The rails are rolled with the flanges slightly flaring and

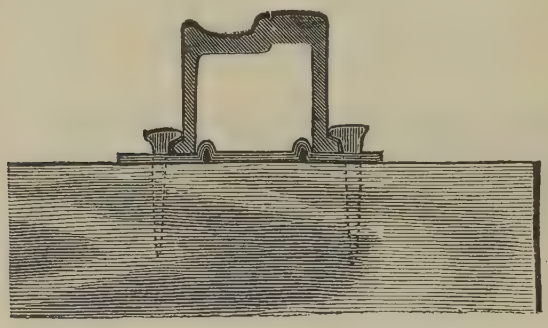


FIG. 562.—BOX GIRDER RAIL SPIKED TO TIE.

terminated with a bead at the lower edge, having an inclined top which is designed to engage with the inclined bead of the clamp, and, from the natural tendency of the web to spring outward, holding the rail and chair firmly together, thus taking up any wear that may occur at the point of contact between them.

The head may be rolled to correspond with any of the forms employed in the other types of girder rail. Designs for special construction to accompany the use of this rail, including curves, switches and chairs for uniting this rail with other types, have been quite fully worked out, and the promoters are competing in the market for a share of the street railway business.

The designs of a duplex rail, shown in Figs. 557 and 563, illustrate a commendable effort to obviate the troublesome joint defects which to a greater or less degree are inherent in every other type of rail, and to provide an all metal structure. This is a comparatively new system, and it has not yet demonstrated its wearing and staying qualities by long and hard service which is the only test that can recommend any system for general adoption. Theoret-

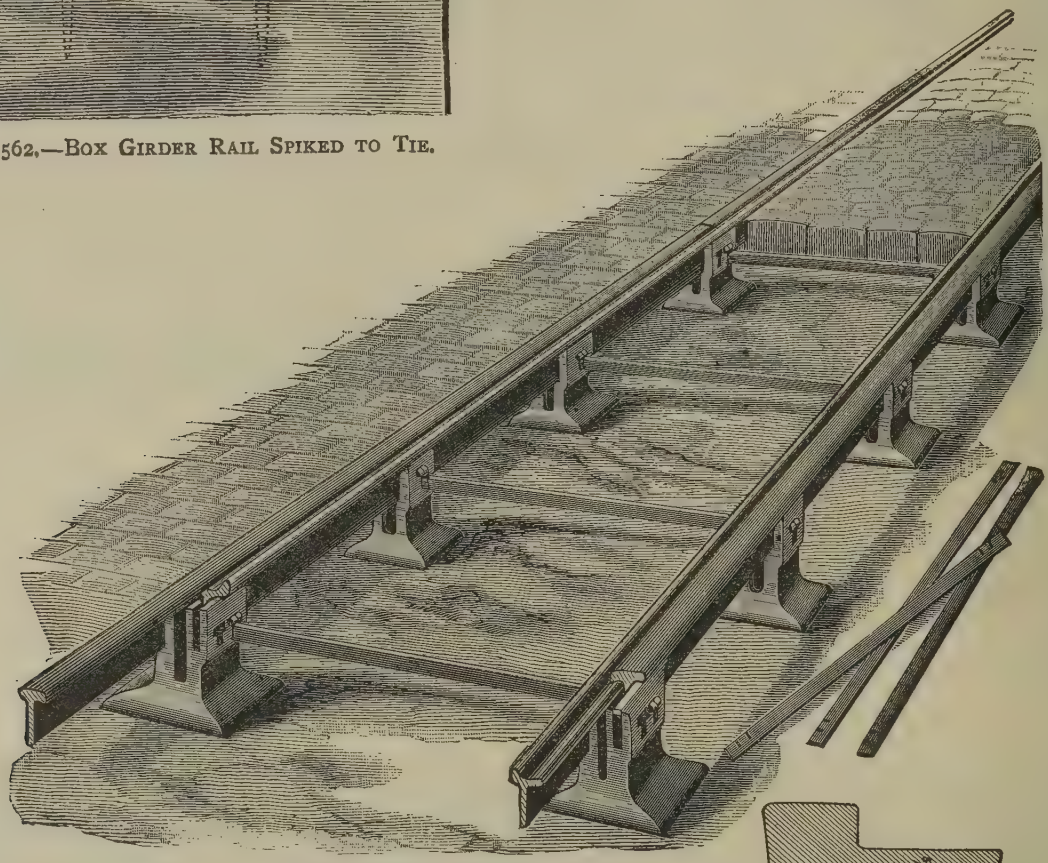


FIG. 563.—DUPLEX CONSTRUCTION.

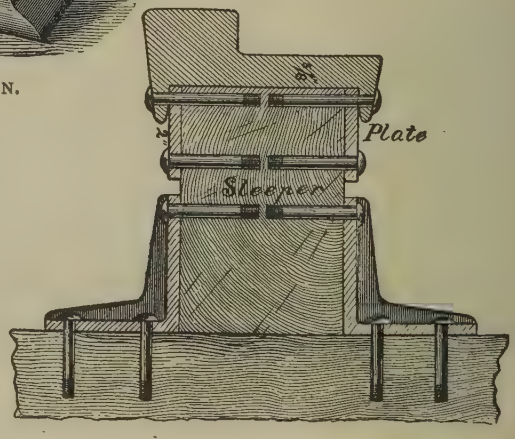


FIG. 564.—TRAM RAIL WITH DEPENDENT FLANGE SUPPORTED ON REINFORCED SLEEPERS.

ically, the mechanical principle on which it is constructed—that of under and overlapping connection—is correct but what depraved traits service will develop cannot be anticipated. It would seem, however, to be worthy of trial.

The system as shown consists of a split rail having two members which constitute the head and tram, which are rolled separately so that each is provided with a plain independent web. When in position the members overlap, forming semi-joints, so that they give to each other mutual support. The cross section resembles somewhat a box rail and it has fair paving features. When worn either member may be replaced without rejecting the other. The top may be rolled to correspond with any of the standard forms, either side bearing, grooved or semi-grooved.

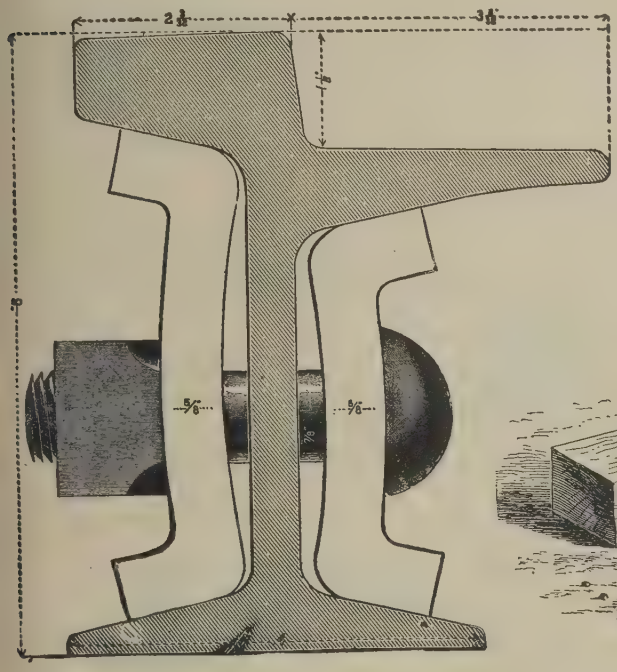


FIG. 565.—CHANNEL BAR CONNECTION.

In order to obviate the use of wooden cross ties and stringers, provision is made for supporting the rails on deep metal chairs which have a broad concave base, and are designed to rest upon the soil where it is sufficiently firm, or upon foundations formed by tamping broken stone, sand and gravel firmly into a pocket excavated for the purpose. The chairs are spaced from two to two feet eight inches between centres, with stout tie bars at every alternate chair, and wedge keys at every chair. The tie bars are provided with notches near the ends so designed as to receive the rail web, which locks them in position and maintains the track to gauge without the use of bolts or nuts. The rails are rolled in thirty-two foot seven inch lengths. Designs for all special work are provided, making a complete system.

A method of track construction which has been designed with a view of employing a tram or flat rail, so as to obviate the joint defects that usually accompany this type of rail, is illustrated in Fig. 564. The essential features of the system consist in placing a flat bottom, heavy rail, having dependent flanges, upon a longitudinal stringer which is faced on each side at intervals with metal plates which are so bolted as to break joints with each other, the rail and stringer. The independent flanges and plates are pierced with oval holes, through which spikes are driven, so that rail, plates and stringer are held firmly together. The stringer is thoroughly protected on the top by the rail and plates, and may rest upon ties or a tamped ballast foundation. How far this arrangement tends to a solution of joint defects remains for service to demonstrate.

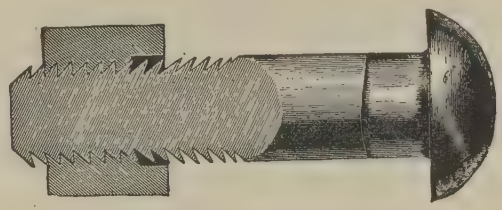


FIG. 566.—GRIP BOLT WITH RECESSED NUT.

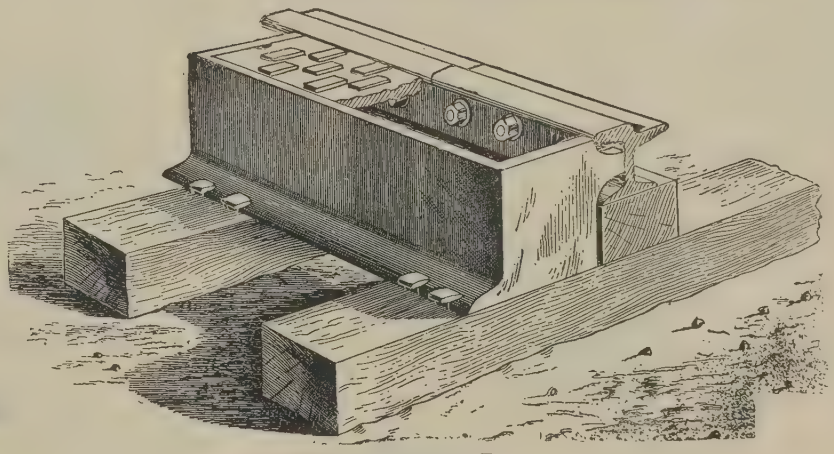


FIG. 567.—JOINT BOX.

THE RAIL JOINT.

The establishment of proper connections between the ends of rails so as to form a continuous line without permitting them to touch each other, except

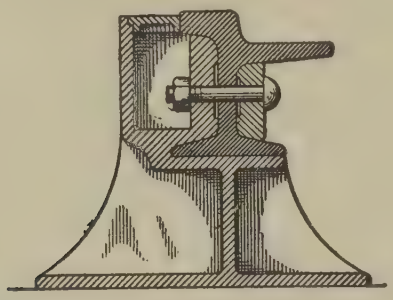


FIG. 568.—COMBINED JOINT BOX AND CHAIR.

when the highest temperature prevails, and at the same time avoid the damaging effects of the space left at the ends, which is necessitated because of expansion and contraction, is one of the most difficult problems that confront the street railway engineer, although it seems comparatively simple. The space required for expansion at the end of rails is in proportion to the length of the rail, and should always be exact, for if too close the rail would be torn from its fastening by the force of expansion, which is estimated to be from six to nine tons per square inch of section, which corresponds to ten pounds per yard, or in a seventy pound rail, from forty-two to sixty tons. The expansion of a thirty foot iron or steel rail is .252

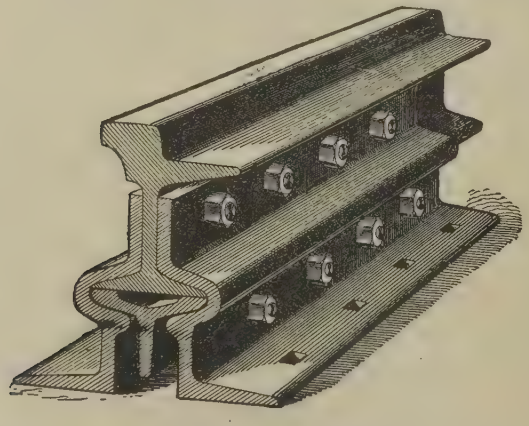


FIG. 569.—STANDARD GIRDER JOINT.

in. or one-fourth of an inch for every 100 degs. of temperature, and the highest temperature of a rail in summer is about 130 degs. Fah., or about 100 degs. above the freezing point, so that when thirty foot rails are laid at a temperature near the freezing point a space of at least one-fourth of an inch should be allowed, and half as much with a fifteen foot rail. At eighty degrees, or fifty degrees below the highest temperature, only one-eighth of an inch is required. When the highest temperature prevails, the rails should be laid so that their ends touch each other.

The joint matter has undergone a long series of experiments at the hands of steam railway engineers, the experiments ranging through various forms of chairs, bridges, fish plates and angle bars, with a tendency favorable to the latter, because they afford additional strength as compared with most other devices ; and yet, those who have had the longest experience in the steam service express the belief that it is practically impossible to provide a joint that will not need constant

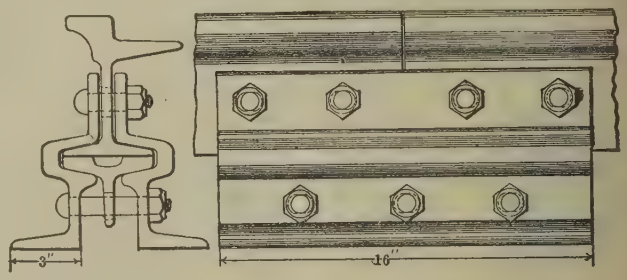


FIG. 570.—STANDARD GIRDER JOINT FOR HIGH RAIL.

attention. This is a rather discouraging statement for the street railway manager, for the rails of his lines are hid away under the pavement where they are not readily accessible ; hence, defective joints may be accepted as the "social evil" of of the street railway system. By employing a properly designed heavy girder rail (not less than eighty pounds per yard), joint defects do not develop so readily as with a lighter rail, but even with the heaviest rail they still exist to an extent not generally realized.

The nearest approach to a solution of the problem, which long service has demonstrated, is the employment of slightly curved steel channel bars on both sides of the rail, where the ordinary types of girder or Tee rails are employed (Figs. 551 and 565). The curve in the channel bars allows them to spring slightly when the bolts are tightened up, causing the plates to wedge in tightly between the head and base of the rail, while at the same time it acts

as a nutlock and tends to prevent the plates from working loose.

In order to secure good results with such con-

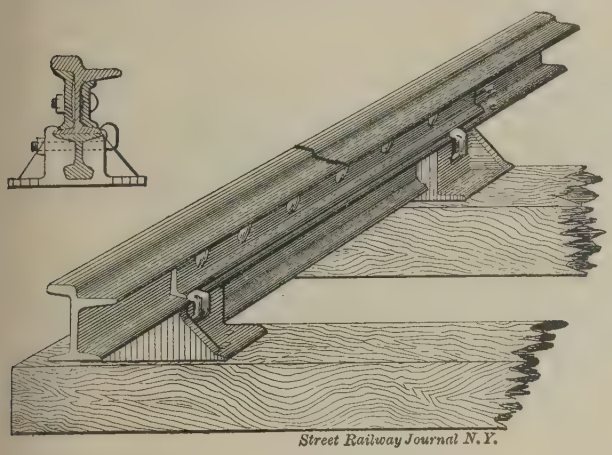


FIG. 571.—BRIDGE JOINT.

nections, it is necessary that the rail be so rolled that ample space under the head and tram and on the base be provided on which the bars may rest, and so drilled as to allow for expansion and contraction. Heavy lock nuts or grip bolts must also be provided, and the nut should have an enlarged chamber or recess on the inside to protect some of the unused threads of the bolt, so that when it becomes necessary to tighten up the bolts, new and clean threads may be brought into service (Fig. 566). Opinions differ as to the proper length of channel best for this purpose. As the ends of the rails go up as well as down, there would seem to be nothing gained by the employment of an extra long bar, and the ordinary length of twenty-eight or thirty inches, with four or six bolts, will doubtless give as good results as the thirty-four or thirty-six inch bar. When the nut is being set up, the bolt should be continually struck with a heavy hammer, and just before the paving blocks are put in place the wrench should be applied and every bolt set up as closely as possible. Almost any type of joint will stand for a time, perhaps a year, without attention, but after a certain period the parts will become worn from constant chafing due to changes in temperature, when they will require readjustment; and that type which requires the least attention is, obviously, the most desirable, without reference to the first cost.

The repair of joints usually necessitates the removal of a portion of the adjacent paving, and, if this is of asphalt or of stone sets grouted with cement or mastic, the difficulty and expense of removing them is quite considerable. In this case it will be found economical to provide at each joint cast iron boxes with removable lids through which access may be had to bolts, so that they may be tightened up at frequent intervals without disturbing the pavement (Figs. 567 and 568). In case a joint tie settles, the boxes are of no

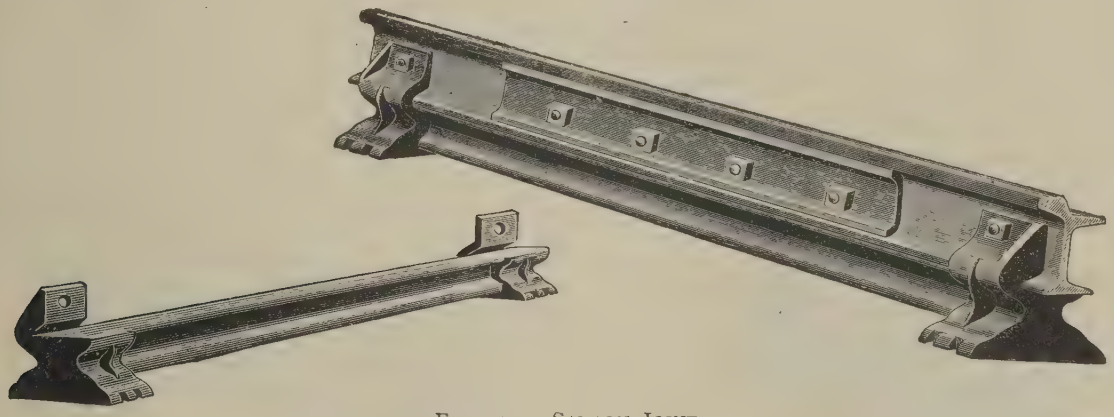


FIG. 572.—SAMSON JOINT.

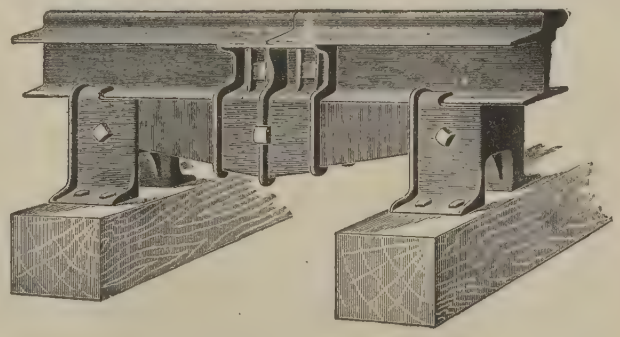


FIG. 573.—BRIDGE JOINT CHAIR.

advantage as it will have to be tamped up, and this will necessitate the removal of the pavement, but for taking the "stitch in time," which is highly important in track maintenance, the boxes are very convenient.

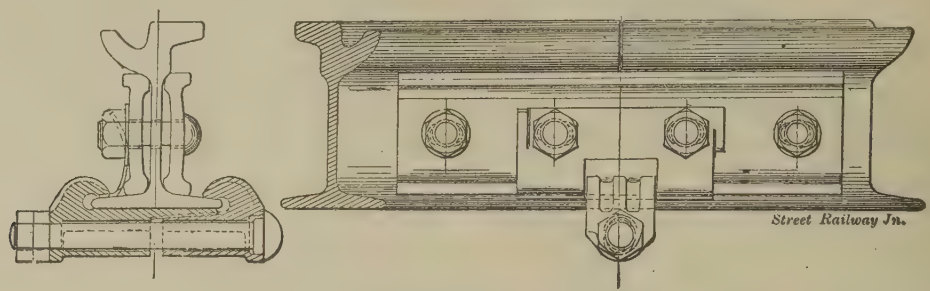


FIG. 574.—CONTINUOUS RAIL JOINT.

It may be stated as a rule that low joints should never be allowed with mechanical traction, for in addition to the damage inflicted upon the rolling stock as before noted, if the rail becomes arched vertically from depression at the ends it will be difficult to ever again maintain it in a level position after the joints are raised, owing to the constant effort of the metal to assume the arched form, resulting in the loosening of the connections under the middle of the rail.

The relative advantage of supported or suspended joints where wooden ties are employed need not be discussed. In treating on track construction for cable lines in the second chapter, we recommended supported joints, as the yokes are usually spaced quite a distance apart, but with ties laid closely, as shown in Figs. 541 and 542, no one can tell which is best. With the adjacent ties so placed that they come entirely under the ends of the channel bars, as shown in the last figure, the joints may be suspended, otherwise a tie should be placed immediately under the joint, except when some form of bridge joint is employed.

The position of joints, with respect to each other, is an important consideration. They should never be laid opposite each other; neither is it a good plan to break joints with the middle of the rail; but where joints are broken about one-third the length of the rail, good results usually follow.

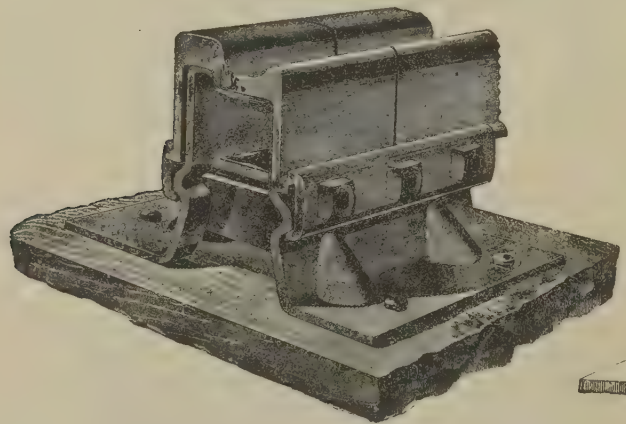


FIG. 576.—NINE INCH JOINT CHAIR FOR BOX GIRDER.

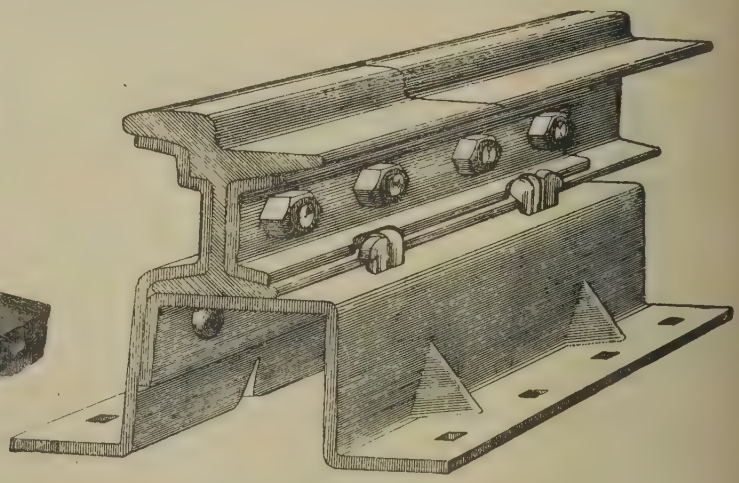


FIG. 575.—BRACE JOINT CHAIR.

Besides the channel bar joint illustrated herewith there are devices in the market which combine the splice bar and bridge principles, some of which have given excellent service. Among these are the standard or girder joint, illustrated in Figs. 569 and 570. This consists of two side clamps of rolled steel, each a girder of great strength, supporting a Tee bar on which the ends of the rails are seated and the

whole clamped by nutlocked bolts above and below. The Tee bar or bridge may be extended so that its ends reach to the adjacent ties, upon which

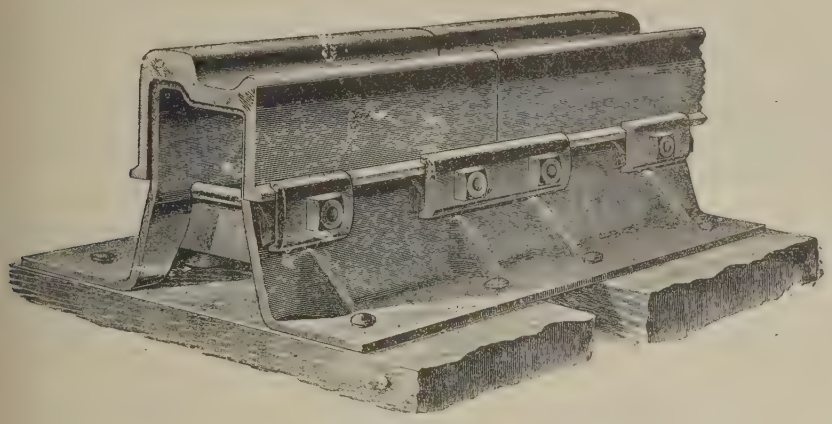


FIG. 577.—LONG JOINT CHAIR—BOX GIRDER RAIL.

it is supported by small two-bolt clamps, making what is termed a three-tie joint which is apparently stronger than the solid rail.

A similar bridge joint is shown in Fig. 571, and consists of an inverted Tee rail, to the ends of which chairs are secured by means of clips. This arrangement also allows of the use of channel bars, the girder being entirely supplementary thereto.

Another joint, which has been designed for the same purpose and known as the Samson bridge joint chair, is illustrated in Fig. 572. It is made by casting steel chairs upon the ends of a three foot section of inverted Tee rail. In cooling, the metal shrinks upon the end of the rail, forming a bridge chair in one piece so that nothing can work loose. The chairs are provided with brace portions having holes which provide for securing them firmly to the rail by means of bolts, which resist any tendency of the rail to cant over. Between the chairs the splice bars are adjusted to the rail in the ordinary manner.

Still another joint bridge is shown in Fig. 573. This device consists of an annealed cast steel bridge or truss supported on and bolted to malleable iron chairs upon which the ends of the rail rest. Near the centre are two steel clips made to conform to the shape of the bridge, while they fit the base and under portion of head and tread of the rail, thereby forming a support for the joint.

A continuous rail joint is illustrated in Fig. 574, in which splice bars are employed to bring the ends to line, but the joint proper consists of a malleable iron clip in two parts, which is placed immediately under the ends of the rails, driven on and then tightened by an inch bolt which draws the parts together with a powerful wedging action and serves to bring the ends of the rail to the same level. A bent slotted plate is attached to the side of the joint, which serves as a nut lock and prevents the clip from shifting.

A brace joint chair is illustrated in Fig. 575.

A long joint chair (Fig. 576) has also been designed for use with the box girder rail. This may be extended to cover two or more ties (Fig. 577), and single clamps may be employed in place of the double clamp shown at the joint.

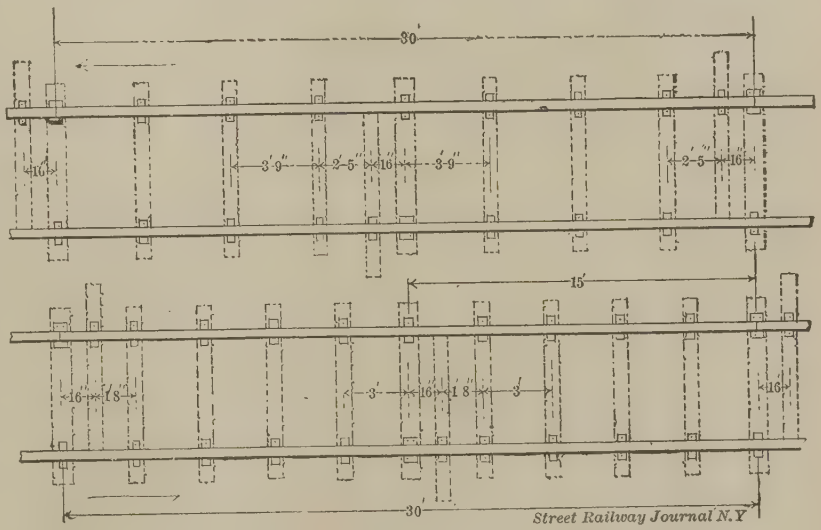


FIG. 578.—EXTRA JOINT TIE EMPLOYED WITH BOX GIRDER RAIL.

Fig. 578 illustrates a method of placing an extra tie near the joint under the receiving end of the rail, as employed with the box girder system, in case a short joint chair is used.

TIE RODS.

The importance of proper connections between the abutting ends of rails is recognized by all, but the value of cross connections is often overlooked. The pavement should not be depended upon for holding rails to gauge; this result should be secured by the employment of suitable tie rods. Brace chairs may answer for low rails spiked directly to the ties, but for high rails, or where the rails are supported on chairs or stringers, it will be necessary to connect the rails by tie rods placed at frequent intervals. The spacing of tie rods will depend somewhat upon the height of the construction, but, ordinarily, they should not be placed more than four or five feet apart. They should be well made of heavy, flat, steel bars not less than one and a quarter inches wide, and from one-fourth to half an inch in thickness, with three-fourths of an inch round, threaded ends. Flat bars are more difficult to make than round bars, but they interfere less with the paving. Tie rods are preferably provided with two nuts at each end to facilitate adjustment, and jam nuts may be employed on the outer ends for additional security (Fig. 579.)

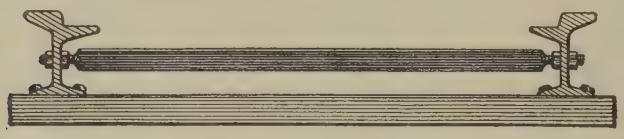


FIG. 579.—TIE BAR.

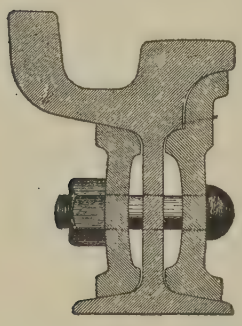


FIG. 581.—GUARD RAIL FOR CURVES.

SPECIAL CONSTRUCTION.

After a street railway is finished, so far as it relates to the road bed, ties, rails and joints, it is far from finished in regard to all the necessary requirements for successful operation. In fact, it may be said in some cases that it is only fairly commenced, for there is urgent necessity, even though the line contains but a single track for curves, switches, crossings, terminal and depot facilities, so that the original cost may be almost duplicated by the different classes of supplementary expenses, especially where intricate and involved construction is required.

It will be impossible to describe in this connection all the different features of special construction, for the conditions differ radically on different lines, and different types of rails have each a corresponding pattern for special work, so that while the different features are being constantly improved a favorite switch of one period is considered inferior to a new kind; hence it will be necessary for the builder to refer to the illustrated catalogues of the rail makers for suggestive details, and in most cases the work of preparing and placing the material must be left in the hands of rail makers or others engaged in this special line of work.

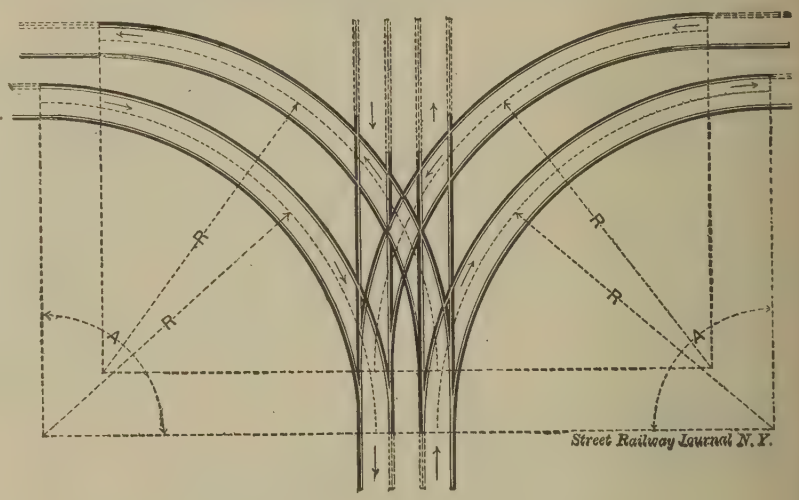


FIG. 580.—DOUBLE TRACK THROUGH Y CURVE.

There are some general requirements, however, that relate to this kind of work which service has developed that may be studied with profit. In the first place, it will be necessary to discard a good many notions and ideas that have formed the basis of practice with animal traction, for on mechanically operated lines, and with electricity, especially, the conditions are entirely different.

Attention has previously been called to the necessity of employing spiral transition curves in the

survey, but this is useless unless the rails are laid accurately to the engineer's lines. Care must also be taken to place the connecting straight track at a perfect tangent to the initiatory curve; otherwise the car will lurch on entering or leaving the curve. The radius of a curve should not be less than thirty-five feet for cars with a six foot wheel base, and double track curves leaving a double track should not be struck from the same centre (Fig. 580).

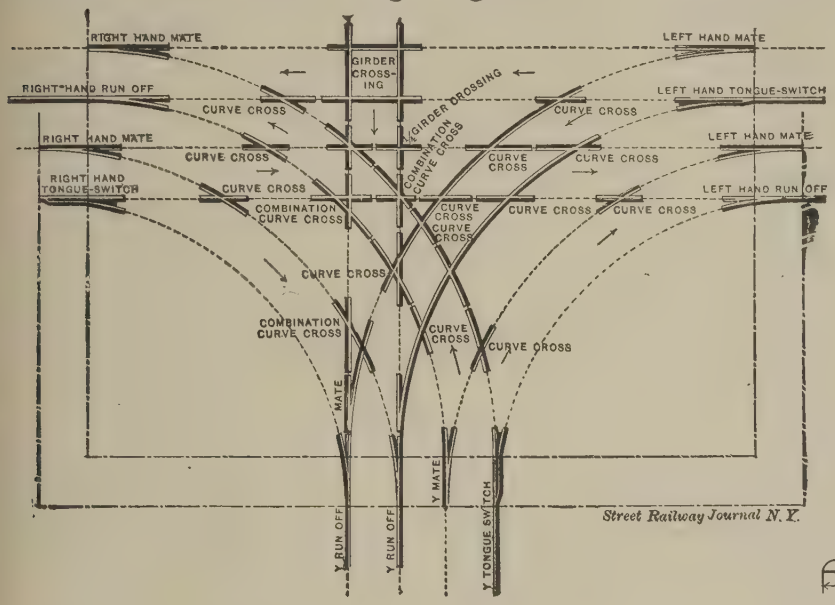


FIG. 584.—SWITCH PIECES.

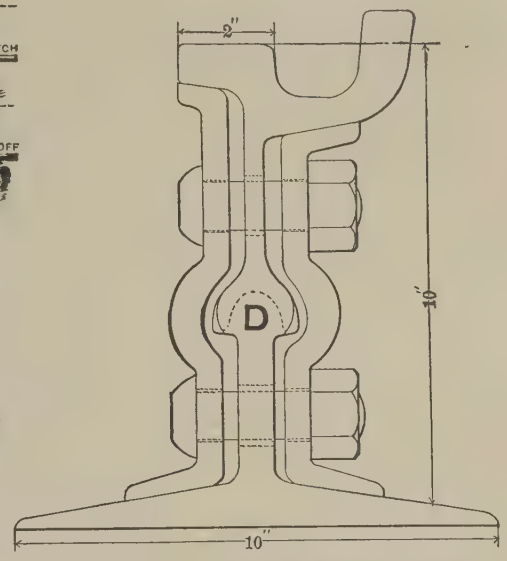


FIG. 582.—ELECTRIC GIRDER RAIL FOR CURVES.

FIG. 583.—DIAMOND TURNOUT.

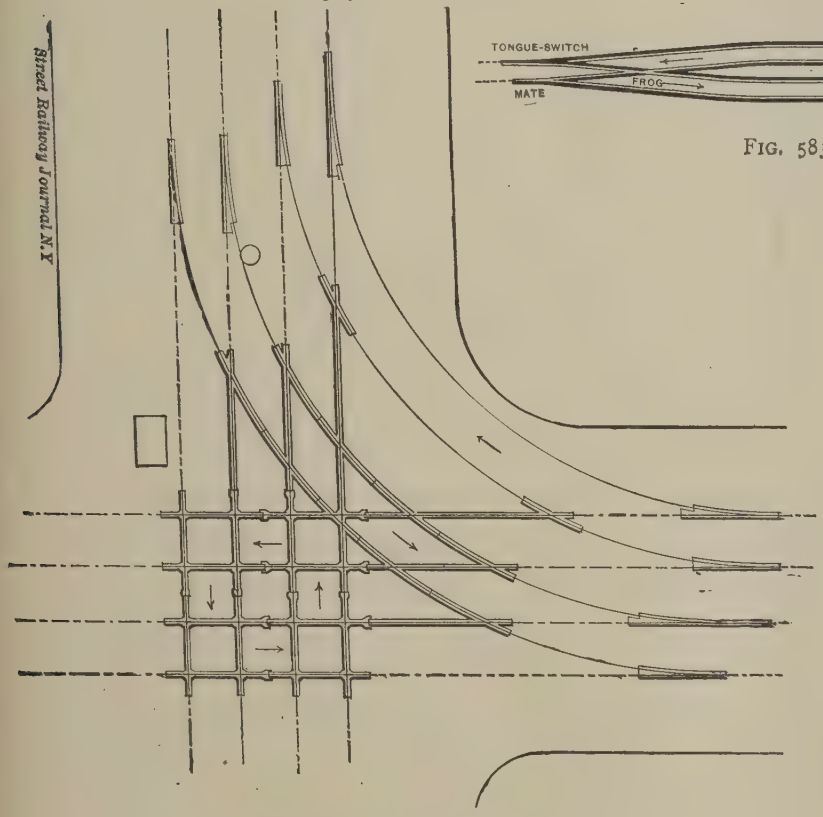


FIG. 585.—DOUBLE TRACK CROSSING AND CURVE.

The inside curve may be made with the longest radius that conditions will allow, and the outside with a radius that will not lessen the distance between the cars. Whatever the radius, the rails should first be bent to the proper arc, for if they are sprung into position after spiking one end, portions of the ends will be straight and the cars will suffer a shock at every joint. The rails on curves are, by some, laid to gauge; others allow half an inch to facilitate the passage of the car and prevent derailment. The outer rail of a curve may be elevated or not, depending upon the radius and local requirements. In some localities permission can not be had to elevate the rail.

Specially designed grooved rails are provided for use on curves with different track systems. One

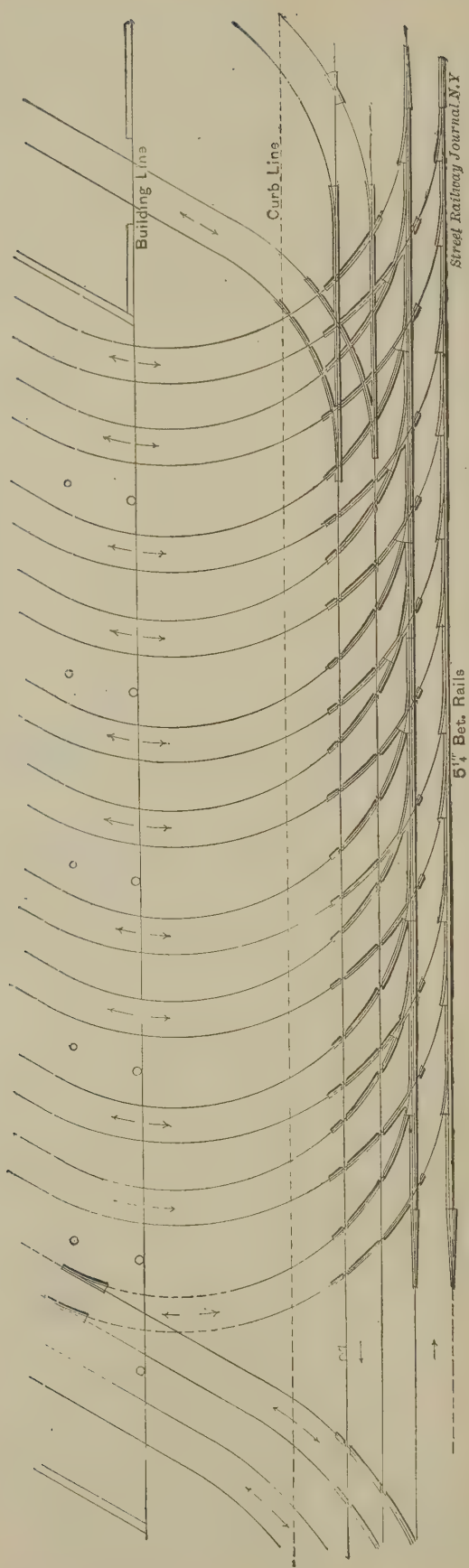


FIG. 586.—BARN CURVES AND SWITCHES.

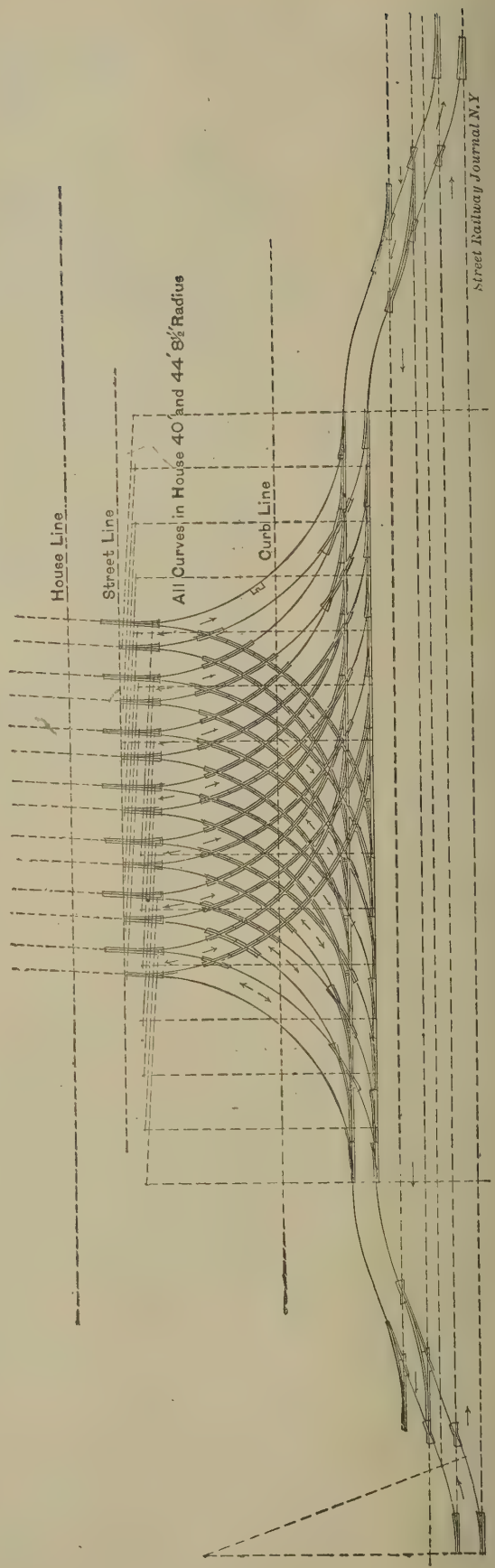


FIG. 587.—BARN CURVES AND SWITCHES.

of those for the girder system is illustrated in Fig. 581; this is laid upon ties, chairs or stringers and properly braced.

Another design known as the "Electric Girder Rail" for curves, is shown in Fig. 582, in which the upper part down to the broken D is continuous, and the foot is electrically welded to the rail at

not be made shorter than 250 ft., and the track should be a perfect tangent to the lead, which should be formed at each end on a curve instead of an angle, and the switch pieces should be of sufficient length to allow of the curve being made with a long radius so that the cars may be run over them at a fair rate of speed.

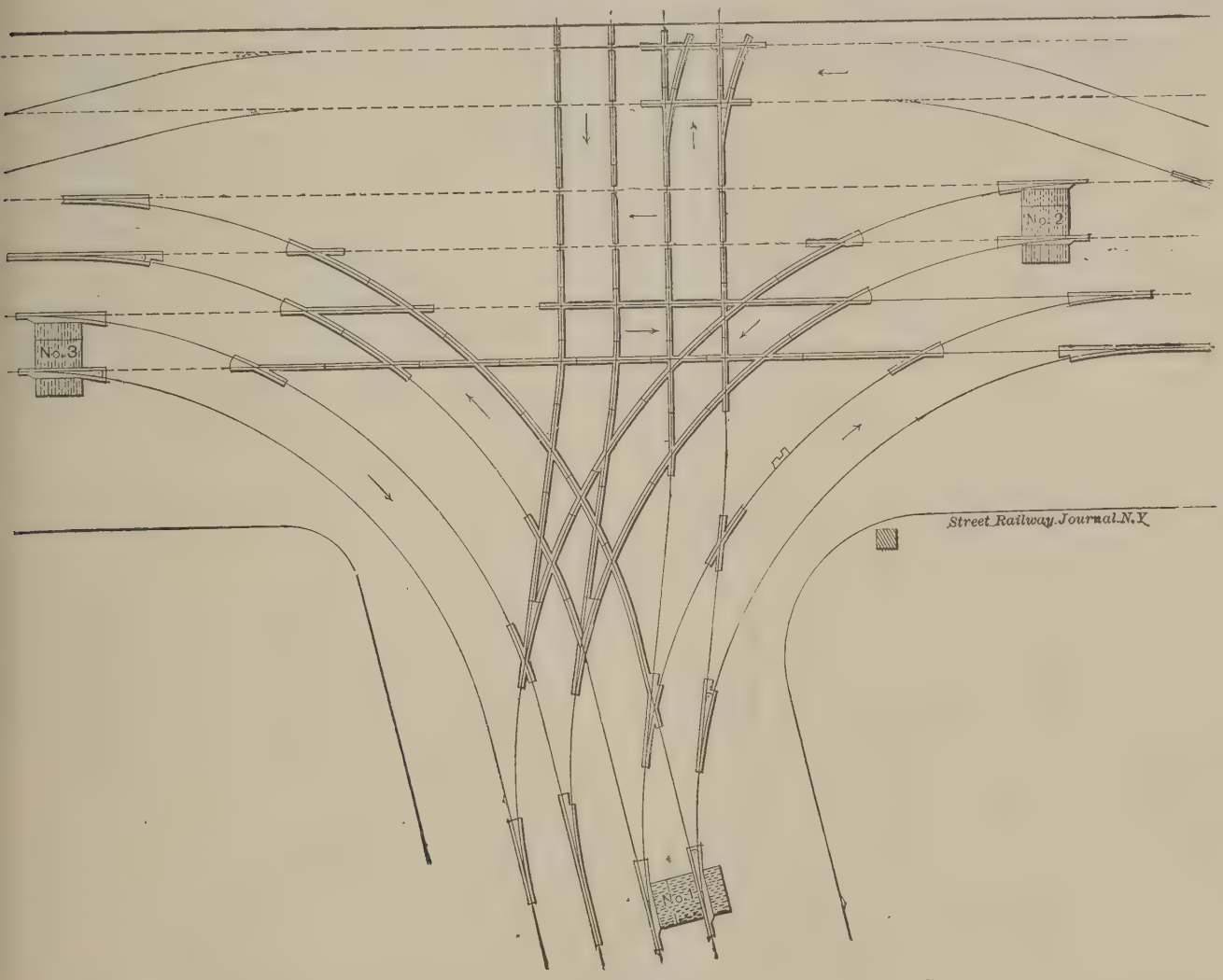


FIG. 588.—DOUBLE TRACK THROUGH THREE PART Y CURVE, WITH CROSSING.

such intervals as correspond to the spacing of the ties.

Rails for curve construction are sometimes constructed with an adjustable guard, so that when the guard is worn out it may be removed and new one substituted without disturbing the rail or foundation.

Turnouts for single track lines are preferably equilateral or diamond shape (Fig. 583), and should

Drop switches or blind switches are not suitable for electric lines, as it is frequently necessary to run in both directions. Cast iron switch pieces and frogs are being discarded, as those made of wrought iron or steel are considered preferable, and are generally cheaper in the end. A construction known as "solid switch pieces" is being quite extensively employed for all special work, and consists of providing, as a foundation, pieces of open

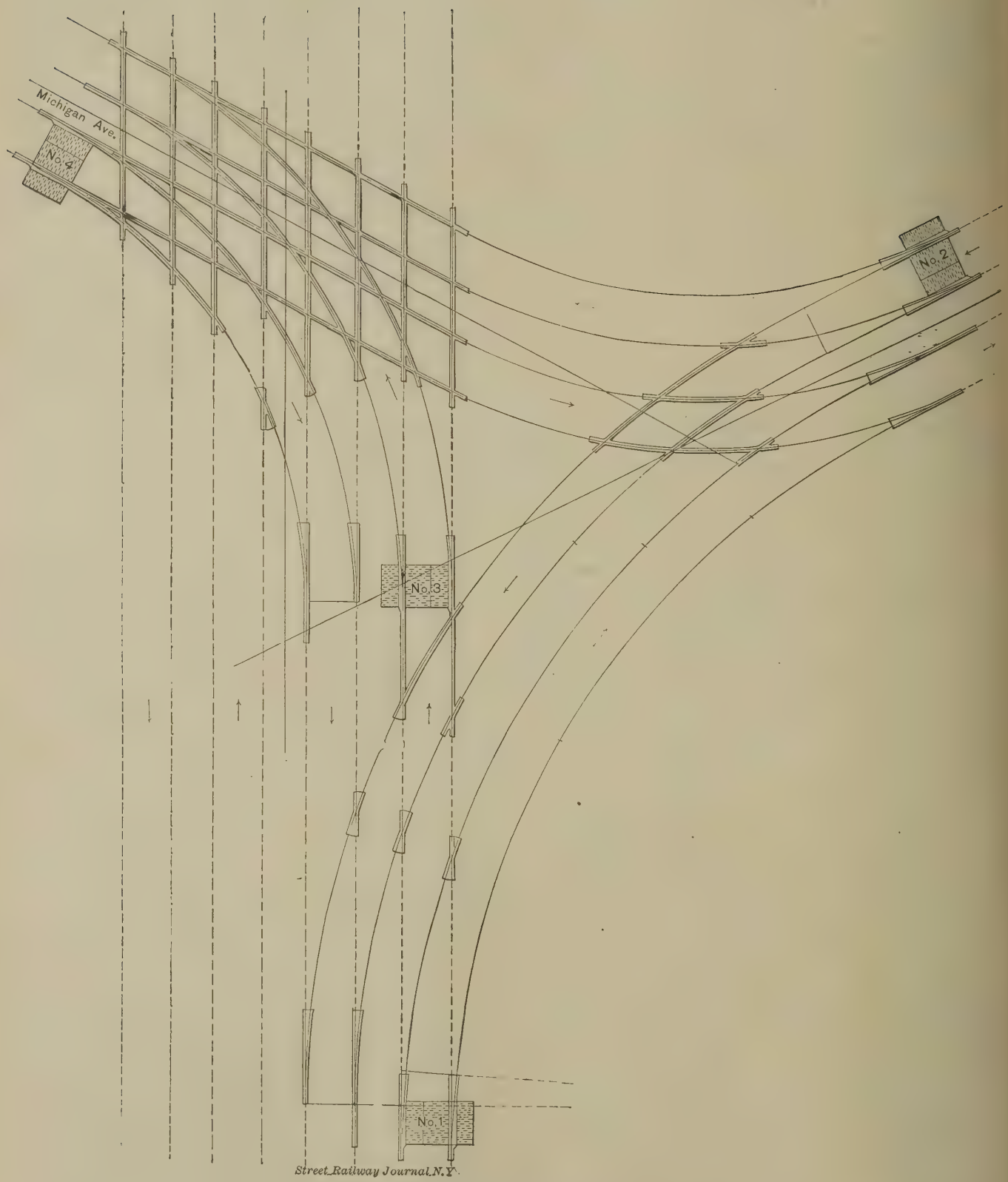


FIG. 589.—FOUR TRACK THROUGH SINGLE CURVE, WITH CROSSINGS.

earth steel, which are cast to proper dimensions nd angles, and to which the steel guard rails are lectrically welded, making a solid and durable onstruction.

In this connection a few illustrations of difficult

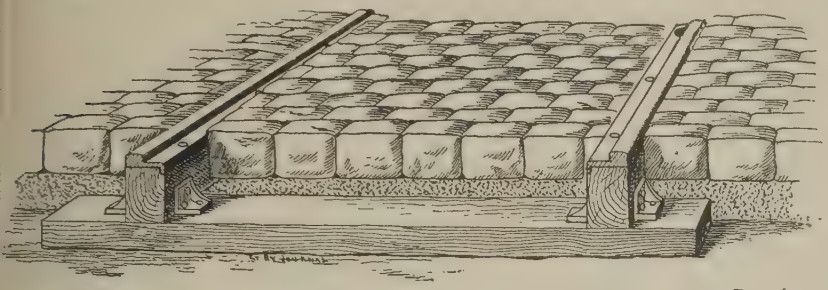


FIG. 590.—STRINGER CONSTRUCTION WITH SIDE BEARING TRAM RAIL.

constructions are given (Figs. 584 to 589) as suggestive designs for curves, crossings, and depot work. The engravings are, in the main, self explanatory, but attention may be called to Fig. 587 in which the individual switches lead off from a third track, thus leaving the main track unobstructed except by a single switch at each end, so that through cars can pass the station on a smooth track.

As a matter of history the ordinary stringer construction with tram rails for horse car lines is illustrated in Figs. 590 and 591. This style of construction, although unmechanical in many respects has served its purpose fairly well with animal traction, for repairs could be made without disturbing

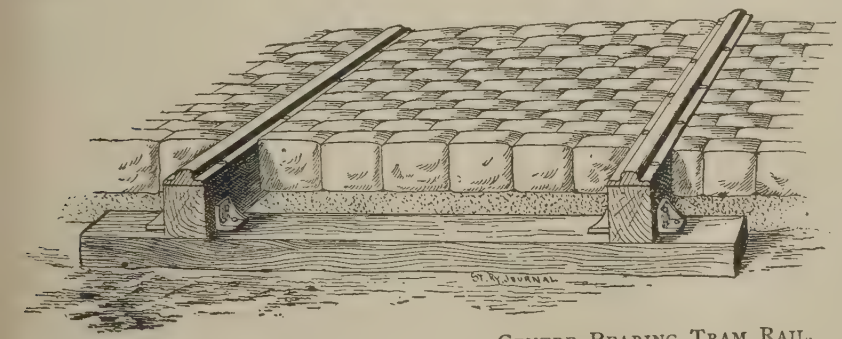


FIG. 591.—STRINGER CONSTRUCTION WITH CENTRE BEARING TRAM RAIL.

the pavement, but it is entirely unfit for mechanical traction, because expansion and wagon traffic soon loosen the fastenings, and the joint plates cut into the stringer, hence it is a waste of money to build it. If a company contemplating electric traction cannot afford to put down a good track and road bed they had better be content with animal traction.

GAUGE.

A considerable difference of opinion exists among street railway men as to the points on wheel or rail from which the standard gauge—four feet eight and a half inches—should be measured. Some measure on the wheel, from the centre of the fillet, others from the tangent point of the tread with the fillet, and still others from the tangent between flange and fillet.

In steam practice the master car builders' standard provides that the distance between the backs of wheels shall be four feet five and three-eighths inches and the standard thick-

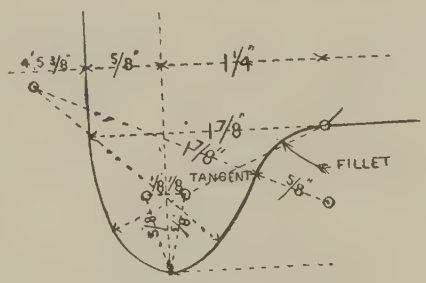


FIG. 592.

ness of the flange shall be one and seven-eighths inches, measuring from the tangent of the tread and fillet to the back of the wheel (Fig. 592). Adding the thickness of the flanges of the two wheels to four feet five and three-eighths inches, we have the distance between the points of tread and fillet tangents four feet nine and one-eighth inches, or five-eighths of an inch wider than the standard. Dividing this by two, we have five-sixteenths of an inch, which, measured off from the tangents on the fillet, locates the point virtually at the middle of the fillet, or the corresponding point on the rounded inside corner of the rail. For street railway practice it would seem to be most convenient in gauging the wheels to measure from the middle point of the fillet, and then allow one-fourth of an

inch margin; and for the track, measure full gauge from the corresponding point on the rails

PAVING.

The paving of the street between the rails and tracks is an important consideration in building and maintaining a line operated either by animal or mechanical power. This matter is usually regulated by the local authorities, but it is important that street railway companies have some knowledge of the different materials and methods employed, for frequently they are able to use their influence to secure the adoption of a system of paving that is most desirable from the operator's point of view.

The essential requisites of a good street pavement, as stated by General Gilmore in his admirable "Manual of Roadmaking," are "that it shall be smooth and hard in order to promote easy draft; that it shall give a firm and secure foothold for animals, and not become polished and slippery from use; that it shall be as noiseless and as free from mud and dust as possible: also that it can be easily cleaned, and shall not absorb or retain surface liquids, but facilitate their prompt discharge into the side gutter catch basins. It should also be of such material and construction that it can be readily taken up in places and quickly and firmly relaid, so as to give easy access to water and gas pipes, and permit of being readily repaired at all seasons of the year."

COBBLE STONES.

have been very extensively employed in this country as a material for forming the path between the rails of such street car lines as were operated by animal power, and were generally considered the best because they offered a good footing for the animals, and could be readily replaced after a street had been dug up, but they are not the safest or the best under mechanical traction, because the stones are liable to become loosened and roll under the wheels. Although entirely wanting in most of the essential requisites enumerated above, and possessing in nearly every particular features which a pavement should not have, doubtless cobble stone pavements will continue to be used to some extent in new towns and cities, and for this reason a brief description of the method of construction is given.

Cobble pavements are usually formed of rounded or egg shaped, hard pebbles, varying from six to ten inches in length, and in width from three to six inches. After the road bed has been excavated they are set side by side in close contact with each other, with their smallest ends down, in a bed of clean, damp sand or small gravel from eight to ten inches in depth. After being set, the stones are firmly settled to their beds by a heavy rammer so as to bring their tops to the same surface, when a layer of gravel two or three inches thick is spread upon the surface and allowed to work its way in between the stones. Particular attention should be given to the selection of the gravel which should contain sufficient iron loam to insure cementing qualities.

Cobble stone pavements require constant repair; and should a stone work loose it should be immediately put back in place lest the adjoining stones become loosened, resulting in rapid depreciation.

STONE BLOCK

paving is generally considered the most durable for heavy traffic. The material, or formation should have the qualities of toughness and hardness and not be liable to become slippery. Granite, trap rock and sandstone formation are extensively used for this purpose. Granite is more satisfactory on some accounts, but trap rock is equally durable. The selection will depend largely on the supply to be had in different localities.

The size of the blocks should be proportioned to the number and weight of the vehicles which will pass over them. The standard dimensions for stone paving blocks in the vicinity of New York are three and a half to four and a half inches in width measured along the street, and from eight to twelve inches in length measured across the street, and seven to nine inches in vertical depth. Over rail ties and other places, blocks of less depth may be used, but the same general dimensions on the top surface should be maintained. It is important that the blocks on any one section be

of uniform depth, so that when they finally settle to their beds the top of each surface will be on the same level. All the stones should be sound and of uniform quality as to hardness, color and grain; no outcrop, soft, brittle or laminated blocks should be used. It is also better, in case the material has been mined from different quarries, that the stones from each quarry be piled and laid in separate sections of the work.

When the blocks of stone are nearly cubical in form, it is termed Belgian pavement, so named from its common use in Belgium. This type of pavement has been extensively used in this country, having been first introduced in New York in 1852. The formation employed here is generally trap rock or syenite, and the blocks are cut with the upper face from three to five inches square, with a depth of from five to seven inches, and the lower or under face somewhat less, giving the block a wedge shape, which is one of its weak points when required to support heavy traffic. For this reason and because the blocks, being wide, provide a poor foothold for horses, this so-called Belgian pavement is falling into disuse in this country. Still, for ordinary light traffic it is durable, and being cheap and easily repaired it is to be preferred to cobble.

The foundation for stone blocks may be formed of gravel, concrete or rubble stone grouted with concrete. The depth of the foundation should be proportioned to the amount of the anticipated traffic—not less than six inches in city streets—and whatever the material it should effectually cut off all connection between the subsoil and the bottom of the paving stone.

In case a gravel foundation is to be employed, the road bed should be carefully excavated to a uniform depth of from ten to thirteen inches, depending upon local requirements and the depth of paving blocks to be used, and all superfluous matter should be removed. Should rock or masonry be encountered it must be removed a little below the level of the foundation or subgrade. The foundation is then brought to an even surface conforming to the grade, and in case there should be found any spongy material or vegetable matter in the bed, it should be removed and the space filled with clean sand, and carefully rammed so as to make it compact and solid. The entire road bed may then, if required, be rolled with a heavy (ten ton) steam roller until the surface is firm and compact. In case the steam roller cannot reach every part, the remaining portion may be tamped or rolled with a small roller. On this foundation should then be placed a layer of sand or fine gravel of sufficient depth.

In laying the pavement the stone blocks should be placed in courses at right angles with the line of the street, except at intersections of streets, and in other special cases, when the courses may be laid diagonally, so as to prevent the wheels of vehicles which turn the corners from following the joints. On steep streets it is a good plan to lay the blocks in oblique course pointing up the grade and meeting at an angle in the centre. The channels thus formed by the continuous joints will facilitate the discharge of the surface water into the gutters (Fig. 593).

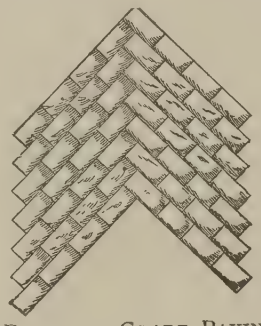


FIG. 593.—GRADE PAVING.

Each course of blocks should be of uniform width and depth, and so laid that all end joints shall be close joints and broken by a lap not less than three inches. If the grouting is to be of sand, the joints between courses should be as close as possible, but if a grouting of mastic and gravel is to be employed the joints between courses may be an inch or less. In case sand is to be employed, the blocks, on being laid, should be covered with clean, fine sand which should be carefully raked until the joints become filled, when the blocks should be thoroughly rammed to a firm, unyielding bed, with a uniform surface conforming nearly

to the grade and crown of the street. When quite a section has been thus far completed it should be covered with a second coat of clean, sharp sand, and receive a second ramming until the work becomes solid and secure. It is usual to employ one rammer to every two pavers.

A more durable paving is secured by providing a concrete foundation upon which to support the blocks, in which case the roadway should be excavated to a depth of sixteen inches below the top line of the proposed pavement, and carefully prepared, as above described, for a gravel foundation. Upon this foundation the concrete is placed to a depth of six inches, except above railroad ties, cable or electric conduits or other subway structures, when the depth may be increased, diminished or omitted as may be necessary.

In preparing concrete, only fresh ground Portland, Rosendale or equally good hydraulic cement should be used. In case Portland is used, the mixture may be made of one part by measure of cement, three parts of clean, sharp sand and seven parts of broken stone. With the Rosendale the proportions may be, by measure, one part cement, two parts sand and four parts broken stone. The mixture should be made in a suitable box or on a platform, and in no case on the pavement or ground.

The sand and cement should be mixed dry, when water of sufficient quantity only to form a mortar is added; the broken stone, having been first wet, should then be added and the mass turned over and worked until the broken stone is completely covered with the mortar, when, after being placed upon the prepared bed, the concrete should be compacted with wooden rammers until it has a clear mortar service, which should be at a uniform grade below the top of the finished pavement.

The broken stone should be sound and solid trap, limestone, or an equally durable formation, and of a size not larger in any dimension than will pass through a two inch ring, and should be carefully screened before using to free it from dust and dirt. The operation of mixing and laying the concrete should be performed as expeditiously as possible, and, if necessary, protected from the action of the sun, wind or frost until set. None should be used which has been mixed more than three hours. The surface should be kept wet until covered with sand, and at least thirty-six hours should be allowed for the mixture to set before the paving blocks are laid. As the work progresses and connection is to be made with a section set or partially set, the edge of the section should first be broken down to free it from dust, when it should be wet in order to make the joint fresh and close.

Upon the foundation a layer of sand or cement mortar should be placed to provide a bed for the paving blocks. In case sand is used, it should be clean, sharp and perfectly free from moisture, and should be spread to a depth of not less than one and a half inches, or of a depth necessary to bring the blocks to a proper grade when thoroughly rammed.

In some cases, especially between the rails and tracks of a cable line, it is desirable to employ cement mortar as a binding material for the blocks. A mixture of sand and cement is spread upon the foundation, and into this soft mass the blocks are pressed to a proper level and left till the mortar is set. The joints may then be filled with a grouting of the same material.

The more general practice, however, provides a bed of sand on which to rest the blocks, and the grouting consists of gravel and a mastic cement. The stone blocks, being laid in courses as above described, with the joints between courses not more than one inch top and bottom, are then covered with clean, hard, hot, dry gravel, of such a size as will pass through a sieve of three-qnarters of an inch mesh and be retained by a quarter inch mesh, and then brushed into the joints until they become filled, when the blocks should be thoroughly rammed, and then more hot gravel applied and again rammed, and the process repeated until the joints are full and the blocks are brought to an unyielding bearing with a uniform surface, true to a roadway on the established grade.

A portion of the gravel at the top of the joints is then raked out to the depth of about two inches,

when the paving cement, or mastic, should be applied while the gravel is still hot. The mastic to be employed for filling the joints may be of coal tar or asphalt, or a combination of the two. In case coal tar alone is used in cold climates it is apt to become so hard and brittle in winter as to crumble from the vibration of the blocks. On the other hand, if clear asphalt is used, it deteriorates after a time and crumbles, and does not maintain a water-tight joint. The following combination, however, has given good results, and is recommended : A cement composed of twenty parts of refined Trinidad asphalt and three parts of residuum oil mixed with 100 parts of No. 4 coal tar. Suitable cauldrons being provided on the work, the mixture is heated to a temperature of 300 degs. Fah., and while still boiling should be poured into the joints until all the interstices of gravel are filled, and the joints are filled flush with the top of the blocks. Dry, hot gravel of proper size, having previously been heated in pans provided for the purpose, should then be spread along the joints and bedded into the cement by tamping with a light rammer or other instrument.

The durability of the pavement depends, in a great measure, on the gravel filling. The cement and mastic filling not only assist in holding the blocks in place, but, being impervious to water, they prevent the entrance of moisture which would tend to soften the foundation and cause the blocks to settle unevenly, or when frozen heave them from their beds. The importance of excluding moisture from paving foundations on cable lines has been noted in the second chapter. It prevents freezing and consequent slot closure.

Besides providing paving blocks of suitable quality and dimensions, attention should also be given to the quality and dimensions of the bridge or crosswalk stones, the manhole heads and the curb and gutter stones.

The North River blue stone or granite, free from seams or imperfections, is regarded as excellent formation for these purposes, and whatever material is used it should be equal in quality to these. The dimensions of the bridge stones should not be less than four or more than eight feet long, except in special cases, and two feet wide and of a uniform thickness which may vary in individual blocks from six to eight inches. They should be dressed on the top so as not to vary in evenness by more than a quarter of an inch, with sides and ends cut square to the full depth, and the ends cut to a bevel of six inches in two feet in order to provide a diagonal joint, which will prevent wheel gutters being formed at the joint, as is the case when the joints run parallel with the street. Those to be set within the railroad tracks should have the ends cut square and be of a length equal to the distance between the rails. The bridge stones should be firmly bedded on a foundation of clean, sharp sand, and be tamped in such a manner as to admit of no further settlement. In some cases a row of paving blocks is laid between the courses of bridge stones, in which case the joints should be filled in the same manner as the joints of the adjacent pavement.

The dimensions of the curb stones should not be less than three feet in length, five inches thick and twenty to twenty-five inches deep. The top should be cut to a bevel of one inch, the front cut smooth to a depth of fourteen inches, and the ends truly squared. When in place they should be backed up by at least a foot of clean, gritty earth, free from clay and loam. The frames and heads for the sewer and water manholes should be cut to the required dimensions.

ASPHALT

in some of its various forms, is rapidly growing in favor as a paving material in those sections of the country where the climatic conditions are favorable. There is some objection to asphalt as a pavement between street car tracks where the lines are operated by horses, on account of its slipperiness and the difficulty of getting at the foundations for repairs ; with mechanical traction, however, and a substantial road bed, these objections are obviated.

The use of this material obviates the intolerable noise which is a necessary accompaniment of stone pavements, and, being a non-absorbent, it is, for sanitary reasons, a most excellent pavement. As

formerly constructed, horses were liable to slip on it in wet weather, but this defect has been remedied in a measure, and animals on becoming accustomed to it do not slip to any great extent. The surface being slightly elastic, the limbs of the horses receive less shock than when driven on a hard surface, and the animals generally keep in better condition, both for this cause, and because, being smooth, there is little resistance to draft.

Asphaltum is known as bitumen and mineral pitch. There are two forms in which the material is used as a pavement, and a capital distinction should be made between them. One is pure asphalt which is of the consistency of rosin, is black like coal and burns more freely than coal. The other is rock asphalt, and consists of shellstone, sandstone and limestone impregnated with from eight to twenty per cent. of bitumen.

Pure asphalt is obtained in great quantities from or near a lake in the district of La Brea on the island of Trinidad, one of the West India islands. This lake is about one mile from the sea and contains about 115 acres, being nearly circular in shape. The surface is formed of irregular, oval shaped, flattened domes, separated by channels of water a few feet wide and a few inches deep, flowing towards outlets, and there are several small islands scattered over the surface and resting on the asphalt, with trees growing upon them, and the borders are covered with a hardened pitch with trees growing over it. The surface of the lake, with the exception of a space of several hundred square feet near the centre, which is soft, fluid asphalt, is sufficiently firm to support the weight of loaded carts. The appearance of boiling of the central portions is due to the escape of large volumes of gas, which keep the liquid mass violently agitated. The asphalt is mined for commerce from different parts of the lake to a depth of about three feet, and also from the shore deposits known as overflow or land pitch. It is excavated with picks and loaded directly into carts and hauled to the shore ready for shipment, being transferred to the ships by means of lighters. The land pitch is hard and brittle, and mixed with more or less foreign matter, and is much inferior to the lake pitch which contains a much larger quantity of bitumen and asphaltic oil, and requires the addition of less residuum oil in the preparation of pavements than the shore deposits, and consequently is more suitable for the purpose.

The natural asphalt rock is mined at Seyssel, France ; Val de Travers, Switzerland ; Ver Wöhle, Germany and other foreign countries, and in this country in Southern California and Kentucky. The foreign varieties are generally of limestone formation, but so far the discoveries in this country are of sandstone formation. The deposits in California seem to have been formed of a loose mound of sand saturated with bitumen, as the ultimate particles are found to be rounded as if by the action of water, but the Kentucky variety is a black sandstone in character, the particles being of a true sand crystal structure, sharp, gritty and flinty. It seems to have been impregnated with the bitumen under heat and great pressure, and is found in veins or strata of various thicknesses, from nineteen to sixty feet. The natural rock asphalt, when it contains from nine to twelve per cent. of bitumen, does not require to be mixed with any other substance for forming pavements. The rock is crushed or powdered, then placed in portable heaters and raised to a temperature of from 200 to 250 degs. which softens the bitumen ; and while still hot it is spread over the foundations and powerfully compressed by ramming, tamping or rolling with hot iron tools, so that the molecules unite, and the mass when cold assumes the essential qualities of the original rock. The imported varieties are considered best, although very good results are had with some of the native material, especially with that found on the Pacific Coast, many of the street car lines in San Francisco being paved with it.

Trinidad asphalt is not suitable by itself for paving purposes, but it is first mixed with sand, powdered carbonate of lime and petroleum oil in certain proportions which have been determined from long experience and careful observation to be the best. The mixture may be varied to suit the varying conditions of climate and traffic. The mate-

rials are mixed together at a high temperature in suitable cauldrons, and while still hot spread two or three inches thick over a concrete or other foundation by means of iron rakes, and then thoroughly compressed by a heavy roller.

The concrete foundations for asphalt pavement may be formed in about the same manner as above described for stone blocks; but the best results are obtained by spreading the wearing surface or paving proper upon an existing stone block or macadam pavement. In this case the surface should be thoroughly swept and cleaned with stiff brooms and the joint filling removed to a depth of two inches. A binder coat of bituminuous concrete should then be spread over the blocks, filling all depressions and bringing the surface to a uniform grade and cross section. The stones composing the binder coat should not be more than one and a quarter inches in their largest dimensions, and, having been heated in revolving ovens, should be mixed by machinery with a coal tar residuum known as No. 4 paving mixture, in the proportion of one gallon of coal tar to one cubic foot of stone, and then spread with hot iron rakes to such thickness that, after having been thoroughly compacted by tamping and hand rolling, the thickness of the binder at any point will not be less than three-quarters of an inch. It will be found of advantage to provide a binding coat, as above described, with any foundation, be it concrete or old paving, as it tends to prevent the wearing surface from crawling and buckling, a defect that is sometimes observed in asphalt pavements.

The foundation having been thus prepared, the wearing surface may be prepared and laid as follows, the method being about the same as that required for this class of pavements in the city of New York:

First an asphalt cement is manufactured, which is composed of pure refined pitch (lake asphaltum), and petroleum oil, having a specific gravity of from eighteen to twenty degrees Beaumé, mixed in the proportion of 100 parts of the asphaltum and from fifteen to twenty parts of the oil. The cement having been prepared, the paving mixture is formed of the following materials and indicated proportions:

Asphalt cement from twelve to fifteen parts.

Fine sand from seventy to eighty-three parts.

Pulverized carbonate of lime from five to fifteen parts.

The sand and asphalt cement are heated separately in suitable apparatus to about 300 degs. Fah. The carbonate of lime, while cold, is mixed with hot sand, and then both are combined with the asphaltic cement at the required temperature. the mixture is then brought to the ground, and while at a temperature of not less than 250 degs. is carefully spread by means of hot iron rakes to such a depth that after being compressed it will have a thickness of two inches. The surface is then compressed by means of hand rollers, after which a small amount of hydraulic cement is swept over it, when it is thoroughly compressed by means of a heavy steam roller, the operation to continue for not less than five hours for every 1,000 yds. of surface.

In order to make the gutters entirely impervious to water, it is recommended that a width of one foot next the curb be coated with hot, pure asphalt and smoothed with hot smoothing irons so that the pavement at this point shall be saturated with an excess of asphalt.

In case rock asphalt is to be used, it is customary to specify that it shall be a mixture of material from the Sicilian and German mines or other mixtures of equal quality, which, ground to a fine powder containing from nine to twelve per cent. of natural bitumen, with from eighty-eight to ninty-one per cent. of pure carbonate of lime and free from quartz sulphates, iron pyrites or aluminum, and be laid without any additions whatever. The process of preparing the powder consists of heating it in a suitable apparatus to 200 or 250 degs., and spreading and compressing it, in the same manner as described for the asphalt mixture, to such a depth that, after having received its ultimate compression, it will have a thickness of two and a half inches, the surface to be rendered perfectly even by heated smoothers, when it is to be

sprinkled with clean, sharp sand. For the reason that the pavements constructed of rock asphalt do not obtain their ultimate compression from traffic for a longer period than that required for the Trinidad pavement, it is recommended that the former be laid to the depth of two and a half inches.

The Trinidad pavements do not become so slippery in wet whether as the European rock asphalt pavements, and offer a better footing for horses, for the reason that the body is composed of sharp sand, while the body of the latter is a smooth, impalpable limestone. There is but little difference in this respect, however, between the pure asphalt and the native rock varieties, for, as stated previously, the particles of the body of the native varities are sand.

In joining asphalt pavement to track rails it is customary in some localities to place a row of paving blocks as headers (long and short stones alternating and toothing into the pavement) on each side of the rails to absorb the vibrations of the rail and provide a track for street vehicles. In practice it is found better to provide a concrete foundation for the blocks, whatever be the foundation for the pavement proper.

Asphalt is also wrought into blocks or bricks and laid in about the same manner as stone blocks. In this form it is principally employed for sidewalks or for footpaths in parks and commons, but has been employed for street pavements in Washington and Baltimore to a considerable extent. While apparently giving satisfaction, asphalt block pavements have not been in service long enough to test their durability.

BLOCKS OF WOOD

set on the end of the grain, have been extensively employed as a paving material in this country and elsewhere for a number of years. The original type of wood pavement was the Nicholson, named after the inventor, in which blocks of yellow or white pine were employed, usually about four inches wide and from four to sixteen inches long and six inches deep. The method of construction consisted in excavating the street to a depth of nine inches, and laying a foundation of clean sand, upon which a flooring of tarred or creosoted pine boards one or two inches thick was placed. Upon this flooring the blocks were set in parallel courses running across the street, the courses being separated from each other by thin battens of pine, and the spaces filled with a mixture of sand, gravel, coal tar or their equivalent.

Nicholson's method has been greatly improved, and in fact is not used in the best European practice, especially as to foundation and the use of battens for separating the blocks. The only successful practice consists in providing a concrete foundation, and placing the blocks close together. Besides pine, chestnut, cedar, red wood, eucalyptus and some other kinds of wood are used, depending upon the supply to be had in any locality. Blocks, hexagonal in shape, possess many advantages, but round, conical and rectangular in shape are also employed, which are laid with various combinations of concrete, tar, asphalt and gravel. To prevent decay, the blocks are frequently creosoted or impregnated with various chemical preservatives. Specifications for wood pavements in some cases embrace the following details of construction: After the foundation has been properly prepared it should be covered with clean sand and very fine, clean gravel to a uniform depth of at least two inches, upon which stringers of pine or hemlock boards one inch thick and eight inches wide, spaced eight feet from centre to centre, should be laid and made to conform exactly to the crown and gutter slope. The stringers being in place, a layer of clean, fine sand should be spread between them and dressed off with a straight edge in such a manner that the sand will form a smooth and compact surface, conforming exactly to the grade of the stringers, after which a flooring of two inch pine or hemlock planks, from eight to twelve inches wide and sixteen feet long, with both ends square, should be laid down lengthways with the street, with the ends resting upon the stringers. Upon this flooring the blocks, of proper dimensions, should be laid, none of the blocks to be larger than ten inches in diameter, and none smaller than

three inches. As the work progresses the blocks should be driven up close together, and no square spaces should be allowed. The spaces between the blocks should then be filled with screened gravel and thoroughly tamped, and refilled and retamped until perfectly solid, when the surface should be swept off with a coarse broom.

Wood pavements are apt to be slippery in wet weather, and are very perishable, both from wear and from decay, and are objectionable, for sanitary reasons, as the blocks absorb the surface liquids and at times give off offensive odors.

Wood blocks are cheaper in their first cost than granite, and in certain localities are necessarily employed because other material is not to be had except at great cost, and notwithstanding the above objections, they have a number of points of excellence to recommend them when new, among which are ease of draft and noiselessness, are easily kept clean, produce less shock to the limbs of horses than stone blocks, lessen the wear of vehicles and admit of high speed, and smooth passage.

As before noted in the second chapter, this type of pavement is not suitable for use for paving the tracks of cable lines, as the swelling of the material from moisture tends to slot closure.

Wood pavements will be found to be a very expensive luxury when laid on streets subject to excessive traffic. Their success abroad is due not only to their expensive construction and careful and costly maintenance, but also to favorable conditions which do not exist in the cities of this country. Among those conditions are the regulations requiring that the wheels of all vehicles be provided with wide tires and that the horses be shod with smooth shoes without calks.

VITRIFIED BRICK,

made from a peculiar clay, is being extensively employed as a paving material in the cities of Ohio and other Western cities, and is regarded with considerable favor. The material is ground fine and then moulded under heavy pressure to the same form and with about the same dimensions as ordinary brick, when it is vitrified by burning so that it will not absorb moisture.

Some manufacturers form the brick with parallel grooves extending around sides and ends (Fig. 594), which become filled when the joints are grouted and serve as a lock to hold the block in place and prevent its being forced up by sub-pressure. The bricks are usually formed with rounded corners on the top to provide a sure footing for horses, and are set on edge on a foundation of concrete or broken stone, with a cushion of sand. The grouting consists of sand or, preferably, of mastic cement.

When the ordinary paving bricks are employed it is customary to lay them in two courses. The first

FIG. 594.—VITRIFIED PAVING BRICK.

course is laid flatwise, with the largest dimensions lengthwise of the street, upon a bed of sand, and the second course is laid edgewise across the street upon a cushion of sand one and three-quarters of an inch in thickness. The joints are then filled with cement or sand.

Brick pavements have long been in use in Holland, and have proved very durable. But the manufacturers of vitrified brick claim that it is much more durable than the Holland varieties, and equal to stone, and that by the new process of manufacture a paving block of uniform size is produced, which has the advantage of being less noisy and more economical than stone. The use of this material thus far in this country has been limited to streets subject to a comparatively light travel, but the manufacturers claim that they are strong enough to withstand the heavy traffic of our large cities.

BROKEN STONE

is extensively employed for roadmaking, and although it may not be strictly regarded as a paving material, the leading systems of stone roads are admirably adapted for suburban lines and streets in small towns, while they are undesirable for large cities.

Two leading methods are employed for making stone roads, known as the macadam and telford systems. The first is constructed by placing successive layers of broken stone directly upon the soil, so that they form a crust on the surface, producing a durable roadway, and which retains the name of the inventor, McAdam.

Roads made with layers of broken stone resting upon a sub-pavement of stone blocks or ballasting, are called telford roads, after Thomas Telford, by whom they were first constructed in Great Britain. The advantages and disadvantages of the "bottoming," which forms the chief difference between the two systems have been the subject of lengthy discussions between their respective advocates. The character of the soil, whether wet or dry, would seem to determine a choice between the two methods, although the latter can doubtless be built somewhat cheaper, for the foundation stones may be of an inferior quality and the labor of breaking them avoided. Of late years little distinction is made between the two systems, and the term "telford" is frequently applied to the foundation of macadam roads. In preparing for the foundation, the surface, subsoil and other matters should be removed to the proper depth, and the bed should be rolled, shaped and trimmed to the required grade in the same manner as described for stone block paving. The foundation stones should then be set close together with their longest sides parallel to the curb, and then firmly wedged by inserting and driving down with a bar in all possible places between them stones of the same quality. All projections and irregularities should then be broken off with a hammer, care being taken not to loosen the stones, and the chips should be worked and driven with the hammer into all the interstices not already filled by the process of wedging, so that the foundation when completed shall present an even but not too smooth surface and be about eight inches thick under the macadam. The material for the macadam should be hard and tough. The most useful are the balsatic and trap rock formations, while certain classes of green stones and selenitic granite are good, as are also the boulders and pebbles of tide water regions. The stones should be broken into pieces not larger than will pass through a ring of two and a half inches in diameter, and then spread (on a dry day) over the bed, the first coat being not over three inches thick and entirely free from earthy mixture. This is then compacted by admitting the travel upon it, or better, by a heavy roller, men being stationed to rake down any ridges that may be formed. When sufficiently consolidated, a second coat of three inches is added, when moisture may be introduced, which will greatly facilitate the union of the two courses. A third coat is added as was the second, and a fourth if necessary. To hasten the smoothness, an inch of gravel or finely crushed stone may be spread over the surface and be passed over by the roller. The stones being properly placed, combine by their own angles, and after a few years adhere together in a smooth, solid surface which is not likely to be affected by the weather or displaced by frost.

It will be difficult to construct a satisfactory macadam pavement on street car lines where tie rods are employed in the construction, as these interfere with a proper bonding of the material. On lines with very heavy traffic it is also difficult to maintain this class of paving in good condition. In any event, roads of this kind need careful attention. The wear of the material, whether mud or dust, should be continually removed and replaced by new materials. A road treated in this manner will need no repairs, as such; but if put in order only at intervals it will need serious repairs.

COST OF CONSTRUCTING PAVEMENTS.

The present contract price for paving the streets of New York including the curb and bridge stones, is about as follows:

For granite blocks on gravel foundation $2.80 per square yard.

For granite on concrete foundation $3.60 per square yard.

For asphalt (either Trinidad or rock) on concrete base with a five year guarantee, $3.00 per square yard.

For asphalt on concrete base, with a fifteen year guarantee, $3.80 per square yard.

For asphalt on an existing stone pavement as a base, with a fifteen year guarantee, $3.40 per square yard.

Vitrified brick pavements on broken stone foundations cost in the vicinity of the manufactories about $2.15 per square yard.

Wood pavings cost usually about $1.25 to $1.50 per square yard, without concrete foundation.

The cost of cobble paving is generally from $1.90 to $2.10 per square yard.

OTHER METHODS.

While the materials and methods of paving above described constitute the principal standards, they do not by any means comprise all the systems of paving that are still in an experimental stage.

Among the latter class may be mentioned those that employ a combination of cast iron and furnace slag, in the construction of which a shell or box of cast iron, shaped like the ordinary paving blocks, is filled with slag and laid in the same manner as stone blocks, or the shells may be combined in groups and laid so as to form a continuous foundation.

Another system provides a combination of cast iron pockets and bottom plates, with the pockets filled with oak blocks which are about three inches square on top and five inches long. The blocks being driven into the pockets about three inches, receive the traffic on the end of the grain. The shells are cast in groups, having five full pockets, four half pockets and four quarter pockets, so that at the joints the adjacent plates help support the same block, dividing the strain and holding the surface even.

Still another method combines vitrified brick on a sheet steel bottom with steel bonds riveted together.

CEMENT.

For the reason that cement constitutes an important element in the construction of paving foundations and cable conduits, and is also used as grouting and for other purposes, it is as important that some knowledge of its nature and manufacture be had as an aid in selecting the best brands as it is to know the particulars regarding other materials, such as stone and asphalt.

The first natural cement known to commerce was produced in England in 1796, in an attempt to imitate the Roman cement which has given to the ancient works of the Romans their lasting character; hence, when a cement was produced that, when mixed with sand, would harden under water, the name "Roman cement" was given to it, and the material resembled closely the Rosendale and other natural cements now manufactured in this country. The process of manufacture, as now adopted in this country, is a very simple one, and consists in quarrying argillaceous limestones or dolomites containing certain percentages of lime, magnesia, silica and aluminum; calcining the broken rocks in open kilns with coal at a light heat and drawing the calcined product continuously from the kilns and grinding it between millstones. The resultant powder is barreled or put in sacks and becomes the ordinary light burnt, natural, hydraulic cement of commerce.

The first commercial Portland cement of commerce was produced in England in 1824, and was made by combining the English chalks with clay from the river, drying the mixed paste in the form of bricks, eggs or balls and calcining at a high heat the material thus produced. The calcination was done in closed kilns, and the product was a clinker, which, when ground, formed a cement of great strength and hydraulic character, to which the name of "Portland cement" was given, because the stone it produced, when used in concrete, resembled in color the well known "Portland" building stone of England. Portland cement differs from the natural burnt, hydraulic cement in that it is an artificial product wherein the proportions of lime, silica and aluminum are combined in uniform proportions, and the material that is calcined in a kiln becomes a new rock or stone artificially produced by the mechanical mixing of the clay or lime, or of the natural rock composing it, so that chemical action necessary for the production of the highest grade cement can take place under the most favorable circumstances. In the natural ce-

ment the rock is taken in the condition that Nature has given it, and the calcination is at a low temperature, so that a large percentage of the material is inert and has no value of a cementing character, while in the Portland cement, burnt at a high heat, all the elements are active.

As above stated, Portland cement is generally made from a mixture of clay and chalk. The foreign varieties are principally manufactured in England, Germany, Belgium, France and Austria. In England the clays are obtained chiefly from the estuaries of the Medway and other rivers, and vary somewhat in different districts. The average composition of good clay for this purpose is as follows :

Silica	54.84
Alumina and oxide of iron	25.08
Lime	0.90
Magnesia	0.80
Carbonic acid	0.83
Sulphuric acid	1.20
Organic matter and moisture	16.35
	100.00

The ordinary soft chalks of the following average composition are also regarded as best :

Silica	1.15
Alumina and oxide of iron	0.78
Lime	54.00
Magnesia	0.25
Carbonic acid	42.50
Organic matter, etc.	1.32
	100.00

In the process of mixing, the proportions of the ingredients are kept as uniform as possible, and to secure this frequent chemical tests are made, so that the resulting cements may not differ greatly in quality. The clay is first broken up, wet ground, and then mixed with chalk and water, in what are termed washing mills, when the mixture is run into vats or backs and allowed to settle. The water is then drawn off, and the solidified mixture is placed on drying plates, which are heated by coal or coke, or, in some instances, by the waste heat of the ovens, until all the mixture is removed. The slurry, as it is now called, is carefully packed into the kilns or ovens with a proper mixture of fuel, coal or coke. The quality of the resulting cement depends to a great extent on the careful performance of this part of the work, for if the slurry be added in too large lumps the outside only will be properly clinkered, while the interior remains an imperfectly burned powder, thorough clinkering being an absolute necessity in order to obtain good cement.

In another process the dried mixture is reduced to a powder and led into an inclined, revolving oven in which gas is employed as fuel, which roasts the fine particles, when they are delivered in the form of cement clinker ready for grinding. By still another process the wet mixture is fed with the hand through an opening in the side of a domed kiln, so that it is subject to intense heat for a short time only ; but a very friable and uniformly burnt clinker is produced. The dry grinding is done between ordinary millstones, or in edge-running mills, and the value of a cement—other things being equal—is due to fineness of grinding. In some cases specifications require that the whole of the cement should pass through a sieve of 2,540 meshes to the square inch, and not less than ninety per cent. shall pass through a sieve of about 5,625 meshes to the square inch, while others require that not over twenty per cent. shall be retained by a sieve of 10,000 meshes to the square inch.

The points of greatest importance in the manufacture are : Uniformity of raw materials ; completeness of the mechanical blending ; the proportion of carbonate of lime ; thoroughness of wet grinding ; the burning ; the flouring ; the aeration and the packing of the finished article.

Knowing, therefore, the facts governing the production of hydraulic cement, one is able to determine which is best for a particular work. It must not be inferred, however, that the manufacture of Portland cement is confined to foreign localities, for while the development in the manufacture of the cheaper grades of cement in this country has been going on very rapidly, the development of the Portland cement industry has received a great deal of attention, so that the ingredients of the product and method of manufacture are no longer shrouded in mystery, but the American cement companies have demonstrated their ability to

make, by improved process, a Portland cement, equal to the best foreign grades, out of natural rocks, and also out of marls and clays which are the chemical equivalents of the chalk and clay of England.

While the consumer should make a capital distinction between Portland and natural cement, he need make no distinction between American and imported Portland except in regard to price. The purchase of cement of whatever brand should be on condition that it be subject to the practical tests which are usually employed by engineers and architects in the purchase of cement. In the case of Portland cement, a chemical analysis is requisite, to show if it has the right composition. One test of proper burning is the weight of a stricken bushel, which should be required to be not less than 112 lbs. to 115 lbs., or a specific gravity test which should not be lower than 3.1 to 3.15. It should also give the usual tensile strength with briquettes at seven, fourteen and twenty-eight days, made with neat cement mixed with a specific quantity of water, and also of briquettes made of two or three parts of fine sand and one of cement. It may be stated, however, in defence of cements that seventy-five per cent. of the defects in concrete arise from imperfect mixing, and not from bad cement.

As previously stated, cements are usually shipped in barrels or bags. In case, however, the material is to be delivered and stored along the work before it is used, it is better to stipulate that it be shipped in coopered barrels, and after being in position it should be carefully sheltered from storms ; and in no case should the barrels be allowed to rest directly on the ground or upon sidewalks, but should be blocked up by suitable underpinning.

COST OF TRACK.

In order to make an accurate estimate of the cost of track construction it will be necessary to know all of the local conditions. These include the character of the soil, local requirements in regard to obstructions in the street, freight charges, cartage and price of material, number of curves, crossings, etc., etc.

The following are given as approximate estimates under ordinary conditions for constructing a line in paved city streets, and will serve as a basis from which to estimate the cost of any line, due allowance being made for local conditions and the ruling price for material. The estimates include the expense of removing the rails and taking up the pavement of an existing line, but do not include the cost of foundation, either of concrete or ballast. If this is of broken stone six inches deep, thoroughly rolled or tamped, or of ballast one foot deep, with space between ties in either case filled with broken stone, the cost will be about ninety cents per lineal foot of double track, or forty cents for single track.

Cost of one mile double straight track laid with a 78 lb. Johnson, 30 ft., girder rail, ties 2½ ft. centres, f. o. b. shop.	
704 rails, 10,560 lineal feet of track, 245.14 long tons, including channel joints, chairs and spikes at $1.25 per foot	13,200.00
4,224 cross ties at 45 cents	1,900.80
Labor, excavating and laying, including teams and superintendence, at 30 cents per foot of single track	3,168.00
Paving with granite blocks, 4 ft. between tracks, two horse paths, and 1 ft. 6 ins. on each outside, 9,282 sq. yds. at $3	27,846.00
Total	$46,114,80

One right angle single track street railway crossing with 78 lb. girder rail, laid complete except paving, will cost about $135.

The cost of one crossover switch with 78 lb. girder rail, laid complete without paving, will be about $525.

One right angle single track, plain curve of 45 ft. radius, with 100 lb. guard rail, ties 4 ft. centres, with chairs joints, spikes, labor, laid complete except paving, will cost $245.75.

Total number of metal parts employed in girder rail construction for one mile of double straight track, with solid steel box chairs or tie plates and four-bolt channel bar connections, ties being spaced 2½ ft. centres, and steel tie rods every 5 ft. 4 ins., will be 60,114. With the standard joint chair spiked to ties, 65,924. With clip and standard joint chairs it will be 91,900.

Cost of one mile double straight track, laid with a 65 lb., 30 ft., Lewis & Fowler box girder rail on chairs, with ties spaced 2½ ft. centres, price of material f. o. b. shop.

704 rails, 10,560 lineal feet, 204.30 tons track including chairs, spikes, etc., $1.20 per ft.	$12,672.00
4,224 cross ties at 45 cents	1,900.80
Labor, teams and superintendence, at 30 cents per foot of single track	3,168.00
Granite blocks, paving 4 ft. between tracks, two horse paths, and 1 ft. 6 ins. on each outside, 9 282 sq yds. at $3	27,846.00
Total	$45,586.80
One righ angle single track street railway crossing, with 67 lb. box girder rail, laid complete except paving	$95.00
Same crossing, steam line	90.00
One crossover switch with 67 lb. rail, 5 ft. or less between tracks, tongue switch at each end (80 ft. radius curves) with all necessary chairs and fastenings, except paving	345.00
One right angle, single track, plain curve of 45 ft. radius, with 67 lb. guard rail, ties 3 ft. centres, with chairs, joints, spikes, labor, laid complete, except paving	244.00

Total number of metal parts employed in this construction for one mile of double straight track with steel intermediate chairs and three bolt, 22 in., joint chairs (no tie-rods required) will be 74,624

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Cost of one mile double straight track, laid with a 66 lb., 32 ft., Duplex girder rail, on cast chairs ten inches in height, with broad base, spaced 2 ft. 8 ins. between centres and steel tie rods every 5 ft. 4 ins.

1,296 sections, duplex rail, 10,560 lineal feet, 207½ long tons.
1,300 cast iron joint chairs.
6,600 cast iron intermediate chairs.
1,980 steel tie rods 2 ins. × ½ in.
9,220 steel wedge keys.

Constituting complete material for one mile track,	$15,500.00
Labor, teams and superintendence, at 30 cents per foot single track	3,168.00
9,282 sq. yds. paving at $3	27,846.00
Total	$46,514.00

Total number of parts employed in this construction (no wood ties used) for one mile of double straight track, with chairs and tie bars spaced as above, 20,416.

CHAPTER X.

DISCIPLINE AND RULES.

Discipline, as defined, includes instruction and government. Instruction is usually given to street railway employes in the form of printed rules, which they are required to study. The rules are supplemented by oral instruction from the superintendent or from a skilled employe detailed for the purpose.

Government consists in directing and securing obedience to the rules. The best code of rules in the world will not insure successful operation; this must be secured by proper supervision, which means frequent and careful inspection, and a judicious use of incentives and penalties. Incentives are better than penalties, provided one is ingenious enough to use them, ingenuity and sympathy being the prime qualities one must possess to make this method of government successful.

The essence of the plan is to employ one honor already attained to get another that is beyond. No matter what was attained yesterday, there is something higher yet, and what has been attained will aid to get to that higher. This is the basis of military discipline. The common soldier is never advanced to be a general at one bound; he must gain one step, become a corporal, then sergeant, then lieutenant, etc. This plan is based on the principles of human nature and operates powerfully to secure successful management. We have not space to further describe them, but leave it to the management to devise such as are suitable.

Since there are always employes with whom incentives have no weight, and also superintendents who have little skill in using them, penalties are equally necessary in the administration of government. Otherwise rules or laws will be brought into contempt. It is not always necessary that the penalty should be severe; it must be *certain* whether injury has resulted or not, and it must tend to train the offender to obey the rules. A penalty should not be imposed with a revengeful feeling, for the influence in such a case would be wholly injurious. Let the offender feel that it is done as a penalty for his neglect or disobedience, not simply because he has displeased the management.

Good discipline depends as much upon the character and natural ability of the manager as upon the character of the employes. Some men will secure excellent discipline with any class of employes, while others would fail, were their employes all saints. It is difficult to name all the qualities one must possess to become a successful disciplinarian. There are geniuses in the street railway trade as well as in war or the state or letters, and the reason why this or that one succeeds is not to be told. It lies in the man; that is all anybody can tell about it. He has a natural force that is no more to be withstood than any other natural force, and with what quality is in him he infuses all who come within his reach, and does not lose himself, for the natural measure of his power is the resistance of circumstances. But such a one does not ignore helps, but rather makes use of all that come to his attention. One who does not have this native force will not succeed in the line of street railway direction with all the helps at his command, and he owes it to himself as well as to his company to seek some other line of work.

While it is not possible to describe all the qualities one should have to become a successful manager and disciplinarian, it is easy to name some.

The one who would govern others successfully must be able to exhibit self government in his own person; the one who has not learned to control his temper, even when tired or harassed, cannot control others; the moral force of a manager is magnified a thousand times by his perfect self control

under aggravating circumstances. Again, one must control his preferences, and not show partiality. The skillful disciplinarian will employ those who may be termed his opponents to assist in operating the machinery of discipline. Again, one must have confidence in himself, and must be a good student of human nature, and must be thoroughly posted in the details of the business; but pedantry is an obstacle that will stand in the way like a mountain.

The most successful manager will always respect his employes. Emerson says the aristocracy of Great Britain have ruled that empire solely by the magic of good manners. The shabby dress, ignorance or stupidity of a man should never prevent his being treated as well as if he were well dressed and clever. It may be noted among rulers that the higher the position the more the courtesy, and the strictest military officers are usually very courteous. It takes off the edge of a command to express it courteously ; it admits the other to be your equal, and will obtain a more prompt compliance than a curt order. It is admitted that the contrary practice prevails to a large extent among railway managers, and many who have never tried the other believe it to be the best policy, but such do not belong to the class named in the first line of this paragraph, "most successful."

The manager should study to inspire every employe with a spirit of loyalty to the company and with the feeling that upon him rests a responsibility to build up the usefulness, success, and popularity of the road. As has been well said, the employes are the real representatives of the company before the public ; and just in proportion as they are civil, polite and attentive, or the reverse, will the company obtain favor or disfavor with the public; but, as a stream cannot rise above the fountain head, neither will the employes be polite, attentive and courteous to the passengers if they have not the worthy example of the manager to follow, rules and regulations to the contrary, notwithstanding.

The selection of employes will aid much in the way of proper discipline. The better the class of men employed, the easier it will be to enforce good rules, and while the question of honesty and faithfulness should largely control the selection of the men, a certain degree of intelligence should be required, for the men are often called upon to use discretion in matters which it is impossible to cover by rules, especially on mechanically propelled lines

The employes of a company are the trusted servants for its revenue, and the financial success of the enterprise will depend largely upon their honesty, fidelity and watchfulness, and these qualities may be cultivated or diminished by proper or improper management. When set after set of employes become more and more dishonest and reckless under a certain management, it is time for the directors to make a change.

In small cities and towns it is usually best to select the employes from among the residents of the place in which the road is located, and such as are favorably known, and well endorsed ; but for lines in large cities, it is claimed that the country bred men make by far the best employes. Appointments, however, should not be made until after an examination into the merits and ability of the applicant, seconded by recommendation, but not through political influence if it can be avoided. Care should also be taken to ascertain if the applicant is seeking employment upon the road as a last resort, or until he can get some other employment; such men will make very indifferent employes, and should not be engaged if others who want street railroad work, and are willing to engage in it as a permanent business, are to be had. The age when first employed should range from twenty to forty years, and it is needless to say that they should be energetic and of good habits. In order to attract and hold good men in the service the pay should be sufficient and the hours of labor not too long.

Once selected and introduced to the business, every possible safeguard should be thrown around the men, and by printed instructions and personal conversation the management should continuously and persistently seek to impress upon them the rightness and advantage of honesty, sobriety and politeness.

It is obvious that no code of rules can be drafted which will meet local requirements in all respects in the different cities of this country, under the different methods of traction employed. The following are selected, however, from sets adopted by the best managed companies, in widely separated sections, and from which may be selected such as may seem best suited to particular localities and conditions.

In preparing a set of rules and regulations for the guidance of conductors, drivers, grip drivers and motor drivers, care should be exercised that they are not too voluminous or complex, but suited to the intelligence of the class of men employed. The fact should not be lost sight of that many men in the employ of street railway companies have not had school advantages, and that it is difficult for them to read and comprehend written instructions. Hence, too much should not be expected of them in the way of becoming familiar with all the rules. It does not argue that none should be prepared, however, and every well regulated company will supply their men with printed copies.

It is a good practice to provide brief extracts from the rules and regulations, embracing such as are most important, and have them printed in convenient form to be carried in the pocket, and with which every employe should be required to become familiar. Such extracts may be printed on the two inside pages of a two leaf card board folder, pages 6×3 ins., which should also contain a list of the time points. (See model, form A.)

It is also a good practice to have the entire code of rules printed in book form, pocket size, with imitation cloth cover, which the employe may carry with him, or keep at his home for ready reference. Such books should be indexed and there should also be a subject index, so that any particular rule may be readily found. It is also a good practice to print with the book of rules copies of city ordinances relating to speed, crossings and disorderly persons, also legislative acts relating to the punishment of offenders on street cars.

In case a number of lines are operated under one management, the names of all such lines and method of traction employed on each should be given in the book of rules.

The names of all streets or avenues crossed, also names of public buildings, squares, depots, ferries, hotels and places of amusement along the line should be printed in the book of rules.

The book of rules designed for drivers of mechanically propelled cars, should, in the case of cable roads, contain an illustration of the particular grip in use, with a brief explanation of its mechanical features, and the names of all its parts.

In the case of electric roads, the particular motor and switch in use should be illustrated and described, with parts named and numbered. This practice will enable the drivers to familiarize themselves readily with the different parts of the machine, and enable them to converse more intelligently with the mechanical superintendent and with one another when the question of repairs or efficiency is under discussion.

Only such rules as are important and can be enforced should be prescribed. When unimportant rules are incorporated in the code there is danger that the employe will form a habit of ignoring them, especially if there is no penalty to follow, which habit is likely to extend to the more essential rules, and a laxity in regard to the whole set will follow.

A specific penalty, however, should never be fixed for the violation of any particular rule; this should be left to the discretion of the manager, and should be inflicted with regard to the disposition and standing of the individual offender.

The following addenda should never follow a rule:

You must never forget this.

No excuse will be received for neglecting this rule.

Failure to comply with this rule will, in every instance, be positive cause for dismissal.

This rule must not be violated under penalty of immediate discharge.

A case might arise where a very valuable man by some slip or oversight might violate the rule, and should he be discharged, as per the rule, it might

be difficult to fill his place, and the company would be the loser.

Employes are to be trained until they are not liable to violate the rules, but if they are peremptorily discharged no opportunity for improvement is given them.

Ordinarily, an employe should not be discharged until there are multiplied charges against him or until the management is absolutely sure that the party is no longer useful to the company. It is the duty of the manager to detect and remove from service all employes who are incompetent or dishonest, that the competent and honest men may be encouraged and protected.

Finally, the greatest care should be exercised in administering reproof, especially when it follows a

FORM A.

INSTRUCTIONS TO CONDUCTORS.

BEE LINE R. R. CO.

Your attention is particularly called to the following extracts from the "RULES AND REGULATIONS" of this Company.

The Conductor's position when on duty and not collecting fares or seating passengers is upon the back platform. Riding inside the car, on the front platform with the driver, chatting with friends or reading newspapers while on duty is prohibited.

The Conductor is required to be on the stand when his leader leaves to direct passengers to the proper car, and give information if required.

Going down, the Conductor on the West side must announce the Streets at **75th, 64th, 59th** and **10th** Streets. **WASHINGTON MARKET,** and the **FERRIES.** Coming up, at the same points.

On the Eastern Division, the Conductor must announce the Avenues when crossing 59th Street, also announce **34th, 23d, 14th, HOUSTON** and **GRAND** Streets. and the **FERRIES.** When requested to stop at any Street or point not enumerated above, he must announce the name of the Street or place distinctly and deliberately.

At each Street crossing the Conductor must look up and down the Street so crossed, in both directions and upon both sides of said Street, beckoning when in doubt as to any approaching passenger. It is better to stop five times and fail to get a patron than to fail to stop once when by so doing one might have been secured.

IN THE TREATMENT OF PASSENGERS universal politeness is required, the temper must always be controlled and a wordy war never engaged in. It requires two to make a quarrel; a passenger, however abusive, is under no circumstances to be replied to in kind. A quiet, pleasant, good humored way, obliging and thoughtful manner will win and conquer, and this kind of behavior is always to be cultivated. Profane language or loud talking must never be indulged in by a Conductor.

BEWARE OF ACCIDENTS. Take no risks, go out of your way to be on the safe side. In case of an accident be sure to get as many witnesses as possible. Be certain that their names and addresses are rightly understood. Always have with you a pad of Witness slips, and promptly distribute them, giving one to each passenger. Endeavor to have the slip filled out by each passenger in his own handwriting.

If a passenger, intoxicated, or for any other just cause must be ejected, the Conductor must first stop the car, return the fare if paid, and remove without violence the one to be put off, and in every case take the names and residences of witnesses, either persons on the car or street or both.

TIME. The Conductor is responsible for time. His watch must be compared with and set by the Starter's regulator. The driver must obey the Conductor's order; any failure on his part to do so must be reported by the Conductor.

The Conductor must not carry free passengers other than those whose names or, if police, numbers, upon the trip record will show have ridden free.

The Conductor must be cleanly in personal appearance, and abstain from smoking and the use of ungentlemanly or unnecessary conversation while on the car. He must never visit a saloon.

NECESSITIES: — Honesty, Temperance, Industry, Attention, Accuracy, Politeness, Neatness.

Without these qualifications a Conductor or Driver must in a short time prove a failure.

THE OBJECT of the alarm is to notify each passenger that his fare has been collected.

THEREFORE the Conductor must sound the alarm distinctly in the presence of a passenger before collecting another fare.

THE CONDUCTOR must invariably carry **TWO DOLLARS** in change (as a working basis) in addition to the money received from passengers.

The down part of the **TRIP SLIP** must be made up and deposited with the Starter at the Ferry after entering the amount on the up Slip.

THE UP part of a record of the whole trip is to be made up at the Depot, and turned in to the Receiver with the money.

MEMORANDA of transfers, passengers, etc., to be made on the back of the Slip.

TALLY on Slip, trunks and packages at time fare is received.

THE MONEY RECEIVED is the record to the Conductor of the number of passengers carried. Exercise the **GREATEST** care to see that this is always correct.

TIME POINTS.

WESTERN DIVISION.				EASTERN DIVISION.			
Down.		Up.		Down.		Up.	
Depot		South Ferry		Depot		South Ferry	
To 42d st	6 m	To Pier 1	5 m	To 59th st	8 av 7 m	To Wall st	6 m
" 30th "	7 13	" Cortlandt	5 10	" "	6 " 4 11	" Roos'v'lt	5 11
" 14th "	8 21	" Chambers	5 16	" "	3 " 5 16	" Rutgers	5 16

oluntary report on the part of an employe of mis-aps. Some superintendents defeat their own pur-oses by a habit of indiscriminate censure when nything goes wrong. As a rule, it is better not o administer a reproof immediately after a man eports his own mishap; better wait until the natter has been investigated; then, if it is found ecessary to reprimand him, do it in such a way hat he will still retain his self respect, and be even rompt to report the most trifling accidents, for ccidents are likely to come to the most skillful; ut even good, conscientious employes will learn o neglect their reports when they find that these re to be followed by remarks reflecting, even lightly, on their judgment and skill.

The management of a street car line will find it f advantage in case of a serious accident being re-ported to require that the employe reporting the same make oath to his statements as soon as possi-ble after the report is handed in. Such sworn statements may prove of value in case litigation follows:

The following is given as an index to subjects for a book of rules for conductors:

Accidents.	Penalties.
Advertisements.	Personal Habits.
Appointment.	Police Assistance.
Badge and Uniform.	Position and Duties.
Blockades.	Reporting for Duty.
Bonds.	Resignation.
Care of Car and Furniture.	Responsibility.
Collection of Fare and Change.	Right of Way.
Crossings and Switches.	Signals.
Damage.	Speed and Headway.
Deportment.	Stopping.
Disabled Car.	Switches and Crossings.
Discretion.	Time.
Duties and Position.	Tracks.
Fire Department.	Transfers.
Freight and Parcels.	Treatment of Passengers.
Headway and Speed.	Trip Reports.
Lost Articles.	Uniform and Badge.
Parcels.	

An index of sub-headings should also be printed to correspond with each rule.

The following rules for the guidance of conductors are suggested, from which a selection may be made to suit each particular case of locality and method of traction:

RULES FOR CONDUCTORS.

APPOINTMENT.

Rule 1. The conductor will be placed at the foot of the extra list on being appointed, and promotion will be made by seniority from the extra list to the regular list only.

2. When a regular conductor is late for his car, resigns or is discharged, extra No. 1 is entitled to the car, and the remaining extras will be promoted in regular order.

REPORTING FOR DUTY.

3. A "regular" must report to the starter or other person in charge for duty, at least ten minutes before the starting time of his car.

4. An "extra" must report ten minutes before the starting time of the first car; and if not assigned to duty must report at all times during the day when cars are to be sent out. An extra failing to report promptly will be liable to have his name dropped to the foot of the list. Anyone detailed for emergency duty must remain at the car house during the time for which he is so detailed, and be ready to respond immediately if called upon.

5. A regular or extra on reporting for duty must immediately enter his name and number of car and badge on the register provided for that purpose, and then consult the bulletin board and order book, that he may have a thorough knowledge of all orders and notices issued.

6. The conductor must have his car ready to leave the car house promptly on time.

7. Assistance must be rendered in taking cars out of the car house and in putting them away.

8. A conductor will only be relieved from taking out his car by personal application, except in case of sickness, when notice must be sent to the starter to relieve him from the penalty for neglecting to report, in accordance with the rules governing excuses, and posted at the depot.

9. A conductor who desires to be excused from duty must notify the superintendent by note the day previous. Leave of absence for more than one

week can be obtained by personal application only.

10. In case of a snow storm, all conductors not at work must report to the foreman for orders.

BADGE AND UNIFORM.

11. When on duty the conductor must wear the prescribed uniform which must be kept clean and neat. The official badge must be worn in plain sight on the cap or on the left side of his coat, and kept bright. It is to be delivered to the starter or receiving clerk at the end of each run. Exchanging badges or duties without the consent of the superintendent is forbidden.

12. Under no circumstances may an employe lend his badge to any person. The loss of a badge must be reported immediately to the superintendent. Badges must be kept bright and clean, and the badge ribbon never allowed to remain in front of the number. All badges must be returned to the office on leaving the service of the company. In severe winter weather, when Scotch caps are permitted, the badge number must in all cases be transferred with the cap.

DEPORTMENT.

13. The conductor must be civil, polite and attentive to all passengers, under all circumstances, giving special attention to ladies, children and elderly persons, while getting in and out of the car, and must answer proper inquiries, but avoid unnecessary conversation with passengers or employes. The conductor will hold himself in readiness at all times to answer the call and obey the orders of those in authority. He shall treat them with respect, and in his demeanor to his associates be cautious and considerate, refraining from disputing or quarreling, guarding himself against envy, jealousy, or other unfriendly feelings, and refrain from all communications to their discredit, except to those in authority, whom it is his duty to inform of every neglect or disobedience of orders that may come to his knowledge, reporting to each such matters as properly come within each one's control. He shall conform to the rules and regulations of the company, and observe the city ordinances.

14. Should any difficulty occur with a passenger, the conductor must not get angry and use uncivil language, even under the greatest provocation, as no excuse will be taken for rudeness and sarcasm under any circumstances.

15. A conductor must neither give to nor receive from any driver, or other person in the employ of the company, any fee, gift, gratuity, cigars, treat or other entertainment whatever, and the name of any employe who shall claim, directly or indirectly, anything of the kind must be reported promptly to the superintendent.

16. All complaints must be referred to the superintendent.

PERSONAL HABITS.

17. The conductor must abstain while on duty from smoking or chewing tobacco, from the use of intoxicating drinks, from the use of profane or obscene language and from all improper conduct. Any conductor known to drink intoxicating liquors any time of the day he is on duty, or who enters a place where such are sold, will be held to violate this rule.

18. A conductor must abstain from lounging around the street corners, barn or car shed, and from whistling or shouting to drivers of cars or vehicles when passing them on the street.

19. He must be cleanly in his personal habits; especially must he keep his hands clean for collecting fares, and abstain from reading books and newspapers while on the car.

RESPONSIBILITY.

20. The control of driver and car must be assumed by the conductor, and any abuse of horses or motor, disobedience of orders, or infringement of rules on the part of the driver will not be permitted, and if persisted in, after warning from the conductor, it is the conductor's duty to report the matter in writing to the starter or superintendent, and failure to so report will be considered as a neglect of duty on the part of the conductor. Starting behind time, loafing or too fast driving, driving fast in going on or off turnouts and around curves, failure to answer the bell promptly or to stop the car properly, stopping the car across intersecting streets or over crosswalks, failure to keep a sharp

ookout for passengers in the main and cross reets, failure to signal promptly and accurately r passengers who get on at the front end of the car. relessness in driving fast driving with the view f diminishing the receipts of the conductor, permitting unauthorized persons to drive, sitting down hile driving, the use of profane, boisterous or indecent language or the use of intoxicating liquors, arassing the conductor directly or indirectly, are ll matters which the conductor must promptly report (in writing) to relieve himself of responsibility.

21. Each conductor will be required to have a opy of these rules and regulations with him at all imes when on duty and to make a frequent study f them, and be found familiar with them, and hen he leaves the employ of the company will be xpected to return them to the office.

22. The conductor will be required to deposit $5 s security for signal box keys. Each signal book ill have a key attached to it, and the conductor on luty will be held responsible for book and key while n his possession, and no conductor will be allowed n duty without book and key.

DUTIES AND POSITION.

23. The conductor's place, when not otherwise ngaged, is standing on the rear platform, and he nust not go on the front platform except to collect ares or on necessary business He must not stand nside the car, or lean against the windows, or it on the platform rail, but be constantly on the ookout both ways for passengers who wish to get n or off, and when passengers motion to stop he must recognize such request by a nod. He must not sit in his car or have his attention engaged in reading or conversation with passengers, except on matters relating to his duties, and must do nothing whereby his attention may be diverted from his duties. When on the rear platform, his face should be to the front of the car. If compelled to stand in the car to make change, he must face the rear door. He must not enter the car except to collect fares or answer the call of a passenger, and must not enter the car to collect fares when approaching any prominent street crossing, but after passing it. While on the stand, he must be on the platform to solicit passengers and give information.

24. The conductor must distinctly announce the names of all cross streets, and at the same time observe if any one wishes to get off. He must also announce the routes of the various lines to which passengers are transferred. This rule must be observed until the last passenger has left the car.

25. The conductor must endeavor to be on the rear platform, in all cases, when receiving or landing passengers, and not start his car until they are fairly received or landed, nor shall he allow elderly or infirm persons, ladies or children, to enter or leave the car while it is in motion, to get off or on the front platform. He will also, when passengers are getting off the car, look and see that no car or team is approaching by which they might receive injury. It is his especial duty to provide seats for passengers as far as practicable, especially for ladies. Passengers must not be allowed to stand upon the rear platform or steps when there are seats or standing room inside the car, as they obstruct the passage of those who wish to enter or leave the car, and they should be politely asked to take seats or stand inside the car. The signal must be given to stop the car whenever any passenger makes it known that he wishes to get off, notwithstanding what he may say to the contrary. The conductor must render all needful assistance to passengers having children parcels, etc., and especially to ladies and elderly persons.

26. The conductor of an open car must, when necessary, get off and point out seats to passengers who may desire to ride, but think the car is crowded

27 The conductor must render all needful assistance to the driver when it may be necessary to hold the horses or detach them from the car.

28. Before giving the signal to start on either half trip, the conductor must see that the brake chains are properly fastened when one or more cars are taken on or dropped off from a train. He must lengthen or shorten the brake chain between his car and the car ahead as the case may require. No links or brake chains must be coupled or uncoupled while

the train is in motion, but, to avoid accident, trains must be stopped until proper connections are made.

29. The conductor must not apply the hand brake in passing around the curves.

30. The conductor must not leave his car without permission to converse with employes, or for any purpose, except necessary business, such as removing obstructions from the track. Under no circumstances must the conductor and driver be away from the car at the same time, except when properly relieved

Special for Electric Lines.

31 If a car is new, or has been standing with the trolley wheel off the wire, never put it directly on, but just touch the wire with the side of the wheel; if there is any flash of current, other than a small spark due to the lamps being on, something is wrong. Then keep the trolley wheel off; probably a switch has been left on.

32. Never run the car with the trolley wheel in the wrong direction, except in case of extreme necessity; then very slowly, the conductor having the line in his hand and watching the wheel.

33. A sure and quick way to stop any electrical trouble on a car is to pull the trolley wheel off the wire, but to be careful and not pull it off at a time when the driver may want to use the current to reverse.

34. In the square box above and to one side of the door on one end of the car, or on the outside, just back of the platform under the car, are two sets of safety plugs, one single, the other double, with a lever switch between them. Should the single plug blow, turn off the current, leaving the trolley wheel on the wire, move the switch lever in the safety box to the other side. Should the double plug blow, turn off the current, tie down the trolley pole and wait to be pushed to the shop by the next car. Report the condition of the car.

35. Report at once the slightest irregularity in running, and any trouble noted with the overhead system. Leave some responsible person in charge to guard any low hanging wire till men arrive to repair the same.

36. The conductor and motor man should be able to detect the slightest "out" about a car, and are requested to report fully and ask any question.

37. Become familiar with sounds made by the car, and if any peculiar sound is noticed, use every effort to find its cause and report it.

38. When the trolley wheel leaves the trolley wire the conductor must ring three bells and not attempt to put the trolley wheel on the wire until the car is stopped.

39. The conductor must see that the gate straps are closed, except the outside gate of the rear platform.

COLLECTION OF FARES AND CHANGE.

40. When it is time to collect fares after leaving a crossing or after the passengers have reached their places in the car, the conductor must commence at the forward end of the car, and fares must be collected in tickets or cash from every person over three years of age except city police, as named in the free list below, and he must register the full number of fares or tickets paid by each passenger in the presence of the person who hands the fare, and before collecting from another passenger. When change is to be returned, the fare must first be registered. The conductor must not be engaged in collecting fares at street crossings. When collecting fares on open cars, the conductor must stanb on the right hand foot board, to avoid being injured by passing cars.

41. When fare is tendered for more than one person, there should be a distinct understanding before registering, as to how many and who are to to be paid for. Should a mistake or misunderstanding occur and fares be registered in excess of the number required, it must be rectified by giving back to such person the necessary amount of cash, and not by omitting to register fares collected from others. When making returns notify the receiving clerk of the transaction and also make a memorandum report stating the circumstances. When the conductor is uncertain whether a passenger has paid fare or not, and the passenger insists that he has paid, such passenger must not be removed from the car.

42. Take particular notice of every piece of money tendered by passengers, as, in many instances, trouble and disputes can thereby be avoided. If, through an oversight, short change is given or received, a coin in mistake for one of less value, which is not discovered until the passenger has left the car, the difference must be returned to the office to await the call of the owner, and a memorandum report of the same must be made.

43. Fares for children between three and twelve years, three cents; all others, five cents. Three cent fares must be tallied (with punch or card). Children who have passed the prescribed age must be charged full fare. In all cases of doubt, the age of the child must be asked by the conductor.

WHO RIDE FREE.

44. The president, general manager, secretary, treasurer, superintendent, chief conductor and inspector of the company, firemen in full uniform, policemen in full uniform, and they must be reported by their numbers; conductors, drivers and employes of the company known to be such, wearing a badge, the number and kind of badge to be entered on the trip sheet, specifying the half trip.

45. All others must pay fare in cash, tickets or proper transfer slips.

46. Any one riding on his badge must wear the same as long as he remains on the car.

47. School tickets are good only upon school days, and then only between the hours of 7:30 A. M. and 6:30 P. M.

48. Books of complimentary tickets must bear the names of the persons to whom they are issued, and the conductor must be particular to see that they are used by no other persons. If presented by any other person the book will be retained and returned to the office. The ticket must in each case be detached and cancelled and accounted for in the columns of free.

49. The conductor must obey the driver's call to collect fare from passengers on the front platform (grip or motor car) immediately, and pass on the outside of the car when it is crowded.

50. The conductor must count the number of passengers on the rear platform before entering the car, and if more are there on his return he must collect the additional fare at once.

51. The conductor must account for the number of fares indicated on the register.

52. If a conductor has inadvertantly failed to comply with the rule for registering fares, and the fact becomes known to him on making up his account by his having cash over or tickets unpunched, he must in such case register for them in the presence of the receiving clerk, and make a memorandum report of the same.

PARCELS AND FREIGHT.

53. No trunks, chests, lumber, large packages, baby carriages, explosive materials, or other articles of a bulky nature that may interfere with the accommodation of passengers, or articles which, from their odor or otherwise, would be offensive to passengers must be allowed on the cars. Passengers must hold baskets or parcels on their laps, or place them on the floor; or, if too bulky, they may be placed on the front platform of the car, where they are at the owner's risk. No track brooms, shovels, or other tools must, under any circumstances, be allowed in the car or on the rear platform. Nothing must be allowed to be hung on the brake handle.

54. Fares for trunks, large packages, etc., must be collected, if carried. When collecting fares for baggage, as required by the rules, you must inform the person from whom the collection is to be made, how many fares are required before accepting any. The amount received must be registered the same as fares.

55. The conductor must not take charge of, or become responsible for any basket, letter, package, or article of any kind which a passenger may bring on the car, except those designed for the company.

TRANSFERS.

56. In issuing transfer slips the conductor or transfer agent must punch the hour nearest the time the transfer is made. For example: For a transfer made between 9:30 and 10:30, punch out the "10," which makes the slip good until 11 o'clock, from 11:30 to 12:30 punch out the "12," making it good until 1 o'clock etc. In case of long delays, from blockades (as by fire hose across the track) or

accidents, the conductor so delayed must make proper allowance for lost time, and honor transfers that may have expired by reason of their being late.

57. When a passenger is seen to leave one car and take another, presenting a transfer slip in which the hour has expired or is improperly punched, and such passenger insists that he is entitled to ride under the conditions of transfer, the conductor may carry the passenger without extra fare, provided he has good reason to believe the conductor of the first car or the transfer agent has made a mistake. But such slip must be promptly forwarded to the superintendent with full written report of the whole transaction and name and address of the passenger. Unused slips must be returned to the receiver the same day.

58. In taking up transfer slips the conductor must use great care to see that they bear the proper date, and that the limit has not expired. He must not accept slips at other points than those specified in the transfer slips presented.

TREATMENT OF PASSENGERS.

59. Good order must be maintained among passengers, and drunken, filthy or indecent persons or any in such condition, otherwise, as to make themselves offensive to others, must not be allowed to ride. Passengers must not be allowed to use any profane or obscene language.

60. No persons (children or others) unable to take proper care of themselves must be allowed to ride on the open sections or on the platform.

61. Peddlers and solicitors (of any kind) must not be allowed to ply their vocation on the cars, neither newsboys, except those authorized to sell newspapers on the cars; in which case they must have a written permit or wear their badge conspicuously exposed, unless called on the cars by the passengers, and who, after supplying them, must immediately leave the car.

62. Smoking must not be allowed in closed cars, where the same is prohibited, except on the front platform when front doors and windows are closed, and in open cars on the rear three seats only. The conductor must politely ask smokers to take the front platform, or rear seats, and if they will not do so, must stop the car and require them to alight The conductor must request ladies not to occupy the seats assigned to smokers, as long as there are other vacant seats in the car.

63. Dogs (except lap dogs which must be held by the owner) must not be allowed inside the closed car or on the platform. They may be carried on the rear portion of the grip space, however, free of charge, when they can be placed there without inconvenience to passengers

64. Should it become necessary to eject a passenger from the car for any cause, the car must be stopped at a street crossing, if possible. Quietly but firmly request the passenger to leave the car, first having returned the fare, if paid. In case of refusal, summon a police officer, if one is in sight. If the officer cannot be obtained, expel the party, calling upon the driver for aid, and using no more force than is absolutely necessary, never using the foot to eject or prevent the person from getting on again. Take names and addresses of reputable witnesses, and with them send a full report of the case to the superintendent.

65. The conductor must be polite and courteous to all passengers under all circumstances, giving special attention to ladies, children and elderly persons while they are getting on or off the car. He must be patient and answer any reasonable inquiry in reference to the road or company, and direct strangers and others, when requested, by the nearest and safest way to their place of destination.

66. The conductor must not allow open parasols or umbrellas on open cars, as they interfere with the sight of the driver and with passengers.

67. Caution persons not to get off until the car stops and to beware of passing vehicles.

68. Children must not be allowed to move about the open section of the car.

69. Children must not be allowed to take hold of the car to run with or beside it.

70. The conductor must notify passengers who have their arms out of the windows that it is dangerous, and the company will not be responsible for injuries which may occur to them while in that position.

CARE OF CAR AND FURNITURE.

71. The conductor must keep the car thoroughly clean and tidy at all times. The furniture must be kept free from dust, the windows clean, and the floor free from papers and other rubbish. In muddy or snowy weather, especially, the platforms and steps must be frequently swept. Paper, waste, rags, etc., used in cleaning must be kept under the seats out of sight in a proper receptacle and no article ever deposited between the cushion and the seat. The plated work must be kept well burnished and wiped dry when the car is turned in at night. Allow no one to stand or put his feet on or climb over the seats of the open section, and see that no one scratches or damages the interior finish of the car. The reversible seat backs of open cars and the revolving signs must be turned over carefully. The gates must be placed in position before reaching the terminus of the route, and kept in perfect order. The front door is to be kept closed in cold or dusty weather and the rear door as much as possible. Special care must be taken to adjust the ventilators according to the crowded condition of the car and the condition of the weather, and the blinds on the sunny side lifted when necessary for the comfort of passengers. Curtains on open cars must be kept rolled up when not in use, and not wrapped around the posts.

72. Lamps must be made to give as much light as possible, but not permitted to smoke. Globes and chimneys must be kept clean and no leakage allowed. No lamps or chimneys must be allowed in the cars during the day, but must be left in the lamp room until needed. Lamps must not be lighted until placed in the car, and never set on the seats or stove. Use the match lighter for igniting matches; never strike them on the wood work.

73. The lamp doors must be closed and securely fastened in order to prevent the lamps from falling out and thereby causing injury to passengers or their clothing. When lighting the lamps at night the wick must be kept low at first until the box gets warmed up, when the wick must be raised. In case lamps are required in the morning, they must be lighted before leaving the car house and returned to the lamp room at daylight.

74. The conductor will be held responsible for the condition of the stove while the car is on the road. The fire in the stove must be kept burning and in good condition, according to the weather. Only sufficient coal must be used to make a good fire. Good judgment must be exercised in this respect, and before turning in the car on the last trip the fire must be dumped. All fire and the ashes must be removed from the stove before the car is put away for the night. Ashes are not to be dumped on the street, but are to be put in receptacles provided for the same.

75. Registers must be kept bright and clean, and should a register be lost or injured by carelessness, loss or injury, the conductor will be required to pay for it. When relieved from duty the conductor must return his portable register to the receiver or starter, as he may be directed, and not retain it in his possession when off duty. On no account must the register be lent to other parties, or allowed to go out of the conductor's possession without the consent of the proper officer. If at any time the register does not work perfectly, the fact must be reported to the office and a perfect working register procured in exchange.

76. The car is not to be jumped from the track when it can be avoided by changing cars or by running back to a near turnout.

77. The preservation of the company's property is the special duty of the conductor, and he is to guard it from all unnecessary injury.

ADVERTISEMENTS.

78. Advertisements, show cards, handbills or dodgers are not to be allowed on the car without a written permit from the superintendent, and portable advertisements must be taken down as soon as the date for exhibiting the same has expired.

SIGNALS.

79. One tap of the bell given by the conductor is the signal to stop, two quick taps to start, and three taps to increase speed; on open cars the same signals must be given by a whistle. The driver must give one tap of the bell for each passenger getting

on the front platform. Three quick taps by the driver is the signal for the conductor to set the rear brake at once without waiting to know what the bell is rung for as life may depend on his promptness The signal to start must never be given until passengers are safely on or off the car.

80. When a lady leaves the car the conductor must see that her dress is clear of the car, before giving the signal to start.

81. In all cases before starting he must look on the opposite side to see if any person is getting on.

82. The signal must not be given from the inside, unless the car is crowded so that the platform cannot be easily reached, in which case the conductor must inquire in a loud voice; "All right?" and wait for an answer from some person at the door.

83. When two cars are attached for running, the signal for starting must be given by the conductor of the rear car first and promptly repeated by the conductor of the forward car, each conductor being careful to know that passengers are safely on and off his car.

84 When a passenger rings the bell he must be requested not to do so, in order to prevent confusion.

SPEED AND HEADWAY.

85. No car must be driven at a greater speed than five (or six) miles an hour on W. E. E and A. Streets nor a greater speed than eight miles an hour on any other street in the city

86. The conductor must keep his car on time as nearly as possible, and see that the driver properly performs his duties that he walks his horses around all curves over all switches and across all railroad tracks which intersect the route of the railway.

87 The conductor must not permit his driver to drive nearer than eighty feet to any car; and should the car in advance be loafing or loitering behind time, he must report such fact at once to the superintendent.

88. In case of detention on the route, the horses must not be over urged to make up for lost time. In such cases the headway must be divided, unless the leading car in a blockade is overcrowded when its immediate follower may be driven up close to it.

STOPPING.

89. No stops must be made unless to avoid accidents, except at the street crossings and points which may be designated by a sign board, and when stopping at a crossing, it must always be done at the farther side, so that the foot way is not blocked. The car must not be stopped on bridges or steep up grades except to avoid accidents.

90. Whenever a car (or train) is overloaded or delayed, and followed by another car (or train) within a block, the former train must not stop to receive passengers until there is more room on it or the proper distance between the two trains has been secured. In every such instance do not fail to politely notify persons wishing to ride to take the next train.

91. The conductor must stop to take on and let off passengers in front of all the churches during hours of service, and at prominent hotels. On approaching crossings, or when a stop has to be made, before crossing a street, the first cross walk must be left clear in front of the car.

92. When a car is delayed from any cause, it must not be allowed to obstruct a street crossing or the tracks of another road. Should it be necessary to do so, get help and run the car forward or backward, as may be more practicable.

CROSSINGS AND SWITCHES.

93. At street crossings the conductor must look on both sides to see whether there are any persons wishing to ride.

94. In approaching a railway crossing at grade the car must be stopped at least twenty-five feet from the crossing. The conductor must run quickly ahead, and when assured that there is no danger from approaching trains, he must signal to the driver to come ahead. This signal must not be given until the conductor has reached the crossing. The signal to start must be given and received by the conductor and driver of each respective car only.

95. When two or more cars are operated in one train, and the conductor of the forward car has gone ahead to examine the railroad crossing, the conductor of the second car must go to his own

front platform and see that no passengers are getting off or on either car before giving the signal to the driver to start, and the driver must not advance until such signal is given.

96. The conductor must carefully examine the slot at railroad crossings to make sure that no iron or other obstruction is in the slot, before signalling the driver to advance.

97. The conductor must turn all switches, except when directed to the contrary by special orders, and he will be held responsible for the condition of the switches, if not right when he signals drivers. This applies to all switches whether operated by switchmen or not. Where there is no switchman, switch tongues must be left ready for cars and vehicles following on straight track. Hang the switch hook on the dash, and not on the body of the car.

98. P. Avenue trains moving west have the right of way at the intersection of P. Avenue and S. Street.

All trains on S. Street and P. Avenue lines moving toward the intersection must come to a full stop 100 ft. on S. Street line and 150 ft. on P. Avenue, and then advance on signal given by the flagman.

Cars going south, leaving L. Street between 3:54 and 6:34 P. M. inclusive, and after 9:30 P. M., have the right of way on I. Avenue; at all other times cars going north have the right of way.

ACCIDENTS.

99. Every precaution must be taken to avoid accidents. In case one should occur the car must be stopped at once and every assistance possible given the injured person; he must be taken, if necessary, to a drug store, provided one is near by, or, unless objection is made, a conveyance (ambulance or patrol wagon) must be secured and the injured person carried to a hospital or to his home.

100. Ascertain the name and residence of the injured party, and if seriously hurt, telephone at once to the superintendent's office. The name and residence of all persons witnessing the accident, other than employes of the company must be secured, and at the end of the trip a statement in full of the occurrence, with the names and addresses of witnesses, must be made out on blanks (a copy of which every conductor must have in his possession at all times), and forward at once to the office of the company or to the superintendent

Always have with you a pad of witness slips, and promptly distribute them, giving one to each passenger. Endeavor to have the slip filled out by each passenger in his own handwriting.

101. No information must be given to anyone except the proper official of the company, and conversation about it with others is strictly forbidden. The conductor must not visit an injured person without directions so to do from the superintendent.

102. The rules regarding accidents are of the utmost importance, and every accident, no matter how trifling, or whether it be an injury to person or beast, damage to cars, wagons, or property of any kind, must be reported. For example: If a person falls in stepping off the car, even when the car is at a standstill, and the accident is due entirely to the passenger's own carelessness, and the passenger insists he is not hurt, the fact must be reported as directed above.

103. The liability to accidents on an open car is much greater than on a box car, because of so many places of entrance and exit, and, consequently, the very highest degree of care is necessary when running an open car.

104. The conductor must remain on the platform when passing any public school, where children are on the street, and must in no instance make any motion which will lead a child or other person, jumping on the car, to believe he intends to kick or strike such intruder, except in case of assault. Children must not be allowed to jump on and off the car while the car is in motion, or ride by hanging to the rail or gate, or on the foot board of grip or open cars.

BLOCKADE.

105. In case of a serious obstruction—as by the breaking down of a heavily loaded wagon on the track, requiring more appliances to remove the same than can be found at hand—if possible, telephone at once or send a messenger to the superin-

tendent's office, that men and appliances (wrecking or "hurry up" wagon) may be dispatched to raise the blockade.

106. When it happens that any car ahead can proceed, the passengers, if they request it, must be transferred without argument to such car, giving to the conductor the number and pointing out any who has not paid his fare. Report the facts and number of passengers on the back of the day slip. In case of detention the orders of the time keeper or inspector must be obeyed.

107. After a blockade, forward cars must not stop, except to let off passengers, until the usual space between the following trains is secured, as follows:

If two or three cars (trains) are delayed, the two forward ones must not stop.

If four or five cars (trains) are delayed, the forward three must not stop.

In all cases politely notify persons wishing to ride to take the next train. All above the numbers given must stop to take on passengers.

The above rule does not apply to blockades occurring at any starting point.

POLICE ASSISTANCE.

108. In case the driver of any team refuses to pull out of the track, where it is possible to do so, and persists in driving slowly and holding the car back, call upon the first policeman to compel such driver to turn out. Any policeman refusing to render assistance of this kind, or to assist in ejecting a passenger, must be reported by his number to the superintendent's office.

FIRE DEPARTMENT.

109. In case of fire, the right of way must be given to fire engines, hooks and ladders, hose carts, insurance patrol and other department vehicles, and when they are approaching from any direction the car must be stopped until they have passed. If the conductor sees them first, he must give the necessary signal to stop.

LOST ARTICLES.

110. At the end of each full trip, the conductor must examine his car for lost articles. All such articles must be properly labelled with the name of the conductor, the number of the car and the time and date of finding, and delivered to the receiver. If unclaimed, such articles will be returned to the conductor finding them. Passengers inquiring for lost articles must be referred to the superintendent's office.

111. The conductor must make a return to the receiver of any lost article the first time he reaches the office, on a blank which will be furnished by the company. The return must contain a description of the article, date, number of the car and the name of the conductor, route, trip and time of day when found.

DAMAGES.

112. If glass is broken or other damage is done to the car by passengers, collection for the same must be made, or, if it is accidental and the person refuses payment, the name and address of the party must be obtained.

113. A full report of any damage to the car or furniture, from whatever cause, must be made on the proper blank and forwarded to the office.

114. Damage resulting from collision of cars on switches, curves and intersections of tracks will not be excused, as by ordinary precaution such accidents would be avoided.

DISABLED CAR.

115. In case a grip or motor is disabled while drawing a car, the next train following must push it. In all such cases the driver of the grip which is moving the train must not start till he receives two bells from both ends of the train.

116. The driver of a disabled grip must keep his place on the grip car, sounding his gong, and, when necessary to stop, must give a tap of the bell (at the same time applying brakes), to the conductor next behind him, who, in turn, must give one tap to the conductor of the second car if there are two, and so on until it reaches the driver of the pushing grip. In all such cases special care must be taken and no risks incurred.

117. In case a car is disabled and withdrawn from the track, the passengers must be transferred to the following car, and the number of passengers

and the number of the car to which they are transferred must be noted on the back of the trip slip. The conductor must remain with the disabled car until relieved.

TIME.

118. Each conductor must carry a reliable watch which must be kept exact with the office.

119. The clock at the superintendent's office indicates the standard time of the road, and the conductor must be sure, by frequent comparison, that his watch is exact with it. The time table must be consulted each trip, as various changes of headway occur during the day, and mistakes must be avoided.

120. The conductor must be particular in making "time points," as laid down on the time card. The car must start punctually from the stand, and the conductor must assist the driver to keep on time by giving the signals as promptly as is consistent with the safety of passengers. As the conductor is responsible for the time of his car, he should report any driver who does not start promptly on receiving the signal.

121. The conductor must take his position at least one minute before leaving time, and start promptly on time.

TRACKS.

122. The conductor must report any defect in the road, cars, or horses, or any excavation at the side of the track, to the superintendent or at the receiver's, office on a blank supplied for the purpose.

TRIP REPORTS.

123. The conductor will be furnished with a day blank slip which he must deposit in the receiver's office after finishing the last trip daily, on which must be written the time of leaving each end of the route, the driver's name and badge number, number of passengers carried, amount of fares collected and the number of tickets taken on each half trip. The conductor's badge number, the number of the car and the condition of the register on taking and leaving the car must also be entered. The day slip must be distinctly dated, signed and the several columns correctly footed. All the transfers and passes are to be put into a separate envelope which must be marked with the run number, the name of the conductor and the badge number, and also the number of each kind of transfers and passes, and the same deposited in the letter box, or handed to the receiver. A separate report on the president's slip is also to be made and deposited in the letter box, and the amount of cash fares collected, with the driver's name, the badge number and number of trips the driver makes marked on the back. This slip will be used to make up the pay rolls, and the conductor will have to make good to the driver all errors caused by incorrectness of this slip.

124. Should the conductor, for any cause whatever, change his car after commencing his day's work, he must note the new number on the margin of his card, opposite the half trip on which the change occurred.

125. The conductor must not show his trip card or give any information in regard to his receipts, except to authorized persons.

RESIGNATION.

126. A conductor wishing to leave the service of the company must give notice to the superintendent, at least three days in advance, and must bring in buttons, badge and other returnable property, when settling.

PENALTIES.

127. For any violation of these rules or other neglect of duty, a conductor may, in the discretion of the superintendent, be suspended or discharged and will be held responsible for any loss or damage caused thereby.

BONDS.

128. The conductor will be required to furnish bonds for the faithful performance of his duties, in the sum of $500, with such sureties as may be determined by the superintendent. No order on the company, or assignment of pay will be recognized.

DISCRETION.

129. In all matters not fully covered by these rules the conductor is expected to use judgment and discretion in dealing with passengers, and any others with whom his duties call him to deal.

RULES FOR DRIVERS.

APPOINTMENT.

Rule 1. A driver, when first appointed, is to serve as "extra" in turn, according to time of appointment.

2. When a regular driver is late, resigns or is discharged, extra No. 1 is entitled to the car, and the remaining extras will be promoted in regular order. An extra not assigned to duty must report to the starter ten minutes before the time of the first run, ready for duty, and remain until all runs are called, and at all changes during the day, including the time of running out extra cars.

REPORTING FOR DUTY.

3. A regular must report for duty at least ten minutes before the starting time of the first car; and such as are not assigned to duty must report at all times during the day when cars are to be sent out. An extra failing to report promptly will be liable to lose his place (in order of seniority) on the list. Anyone detailed for emergency duty must remain at the car house during the time for which he is so detailed, and be ready to respond immediately, if called upon.

4. A regular or extra on reporting for duty must immediately enter his name on the register provided for that purpose, and then consult the bulletin board, that he may have a thorough knowledge of all orders and notices issued.

BADGE AND UNIFORM.

5. See rules 11–12 for conductors.

6. When on duty a driver must preserve a neat and clean appearance and must always wear the regulation uniform complete, consisting of a blue suit, with brass buttons on coat and vest, bearing the initials of the company, and the customary cap and badge. No driver will be allowed to go to work unless he is fully equipped with the above regulation uniform.

7. Brass buttons for uniform will be furnished drivers by their division superintendent. These buttons will remain the property of the company, and must be surrendered whenever a driver leaves the service of the company.

SIGNALS.

8. One tap of the bell by the conductor is a signal to stop; two taps to start. Four taps of the bell from the conductor is a signal to the driver not to stop to pick up passengers. Two quick taps by the driver is a call for the conductor's aid. Three quick taps by the driver is a signal for the conductor to set the rear brake at once.

DEPORTMENT.

9. The driver must hold himself in readiness at all times to answer the calls and obey the orders of the conductor and those in authority. He must treat them with respect, and in his demeanor to his associates of the company be cautious and considerate, guarding himself against envy, jealousy or other unfriendly feelings, and refrain from all communications to their discredit, except to those in authority, whom it is his duty to inform of every neglect or disobedience of orders that may come to his knowledge, reporting to each such matters as properly come within their control. He shall conform to the rules of the company, observe the city ordinances, and render his services to the company with zeal, discretion and fidelity.

10. See Rules 13–16 for conductors.

PERSONAL HABITS.

11. See Rules 17–19 for conductors.

12. A driver must not spit tobacco juice so that the wind will carry it on to the passengers.

DUTIES AND POSITION.

13. The driver must get the horses in the morning from the foreman or his assistant, and assist in taking the car from the car-shed.

14. The car and driver are in charge of the conductor, whose orders the driver must promptly obey as long as they do not conflict with the rules.

15. He must ascertain that the conductor is on the rear of the car before starting.

16. He must start the horses, upon the bell signal, slowly and with caution, being careful not to start abruptly.

17. After making a full stop he must not release

the brake, or allow the car to move, until the proper starting signal has been given.

18. Horses must be driven at a steady gait and with a taut rein, the driver keeping the right hand upon the brake handle at all times, and having constant control over horses and car. The horses must be stopped with the reins and not with the brakes. Horses must be started slowly and not allowed to trot until the car has moved at least twenty feet; and, unless in case of danger, the car must not be stopped in less than twenty feet.

19. He must not sit down on the front seat of an open car or lounge against the front door or body of a closed car, when it is in motion. He must be on the alert constantly.

20. He must not bring his car "abreast" of another car while receiving, delivering or transferring passengers.

21. He must assist in making the changes of stock and must water the horses *en route* and at the end of each terminus, being careful not to throw and spill water unnecessarily. Whenever horses are watered on the road they must not be permitted to drink more than one-third of a pailful. More is dangerous, always does more harm than good, and often produces colic.

22. He must notify passengers that it is a violation of the rule of the company for them to enter or leave the car by the front platform, but he must bring the car to a full stop should any person attempt to do so.

23. He must know that all fares are collected from the front, and report to the superintendent any conductor who fails to promptly answer the signal for the collection of fares, or to assist him when it is his duty to do so.

24. In case of refusal by a passenger to pay a fare, drunken or disorderly conduct on a car, he will render the conductor all the assistance in his power.

25. He will call upon the conductor when it may be necessary to take the horses by the head, to hold them or detach them from the car.

26. The driver must avoid all unnecessary conversation with passengers or others, as his duties require his whole attention. He must be civil to passengers, teamsters and all other persons, and be polite and courteous under all circumstances. See rules 13–16 for conductors.

27. In all places where the street is dug open for paving or other purposes, so as to endanger the horses, they must be detached, but they should not be detached from the car when it is in motion unless the conductor is at the brake in front.

28. To guard against accidents the driver is not allowed to sit inside the car, or on the dash rail while the car is in motion.

29. Should he have a baulky horse the driver must not use the whip, but detach the team, walk them around the car once, and then hitch them to the car again. In most cases they start under this treatment. The way to manage a baulky horse is by kindness.

30. The moment any person, wagon or other obstacle is seen on the track, the car and horses must be brought under perfect control. No risk must be taken in so important a matter.

31. In the absence of the conductor, the driver is responsible for the car and its management, and must indicate to the conductor the passengers who enter the car while the conductor is absent examining railroad crossings, etc.

32. The driver must either get down from his car and remove all stones, nails and other things injurious to horses or cars from the track, or call the conductor to do it.

33. The driver is not expected or required to drive a lame or disabled horse.

34. No driver is allowed to exchange positions with any other driver on the line.

35. Whenever the track is icy, and in the judgment of the driver the car will slide, the horses must be detached at top of grades unless driven to a pole.

36. On the Sabbath the bells on the horses must be muffled, and the speed reduced to a moderate pace when passing churches or their immediate vicinity.

37. No person must be permitted to substitute for a driver upon any part of the route, unless special permission is first obtained from the foreman or

starter. Should necessity require a driver to leave a car upon any part of the route, the horses must be left in charge of the conductor or a regular driver.

38. Whipping horses is strictly forbidden. No whip shall be carried without special permission.

Special for Grip Drivers.

39. The grip driver must never start the train (car) until receiving the signal from the conductor, and not then until he is sure no passengers are getting on or off the train.

40. The driver must only start the train on bell taps or whistle, and never on the conductor shouting "all right" or "go ahead." He must be careful to apply the grip gradually and not start the train with a jerk.

41. The driver must not be seated while the car is in motion, or lean against the seats or levers. He must keep his position near the levers, ready to release the grip and apply the brakes instantly. When on the stand, or if the car is detained on the road, the grip must be thrown wide open, and both brakes set firm.

42. The driver must not permit any person, not authorized by the superintendent or proper officer of the company, to handle the levers or to ride within the space provided to work them.

43. The driver must call out, in a loud and distinct voice, the names of all cross streets on approaching them, and observe if any passengers wish to get off.

44. The grip must be applied gradually and firmly, to avoid starting the car with a jerk. After full speed is attained, release a little, so as to equalize the speed of the rope and car, then take a firm hold of the rope again.

45. Whenever it is necessary to release, throw the lever well back, so as to open the grip and not wear the cable.

46. On the down grades, hold on to the cable firmly. Never skin the rope.

47. When running under four bells, always notify persons who hail the car to take the following car.

48. Take no risk in running over vaults. Be sure and release at the marker and hold the lever down.

49. When oilers are discovered at work with a manhole open, the driver must bring the car to a full stop and wait for a signal from the man on guard before proceeding. Oilers are instructed not to give such signal in any case, until the car has come to a stop.

50. The driver must keep a sharp lookout for passengers and stop the train at proper places to receive them, looking in each direction before starting.

51. Trains must stop to receive and discharge passengers at farther crossings of streets intersecting, in the middle of long blocks where the sign is placed, in front of all places of amusement and prominent hotels.

52. The driver must promptly notify the conductor of passengers getting on the grip car or on the front platform of the car by one tap of the conductor's bell for each person, and, if necessary, must indicate to the conductor the said passengers.

53. Except in case of emergency, the brakes must not be applied violently, as brake chains are liable to give way. The grip and brake must not be set at the same time; be sure one is released before the other is applied.

54. The gong must be sounded vigorously on approaching all street crossings, also fifty feet before meeting a car on the other track, and while passing it.

55. The gong must also be used to warn drivers of vehicles off the track.

56. In case persons approaching the crossings or on the track do not seem to hear the gong, the car must be brought under control to avoid danger. Regard every person near the track as deaf or blind. In other words be eyes and ears for other people.

57. The driver must keep scrapers down whenever there is any ice, snow or dirt on the rails, except while passing over cross tracks or switches. Should any scraper at any time get out of order, the fact must be immediately reported to the barn foreman.

58. When approaching the place where the cable is to be dropped, grip drivers must cause the train to move with only sufficient speed to make pick-

ups and must have the train under complete control, so that if the cable should not be free from the grip it can be stopped immediately. While the train is on the pick-up, the following train must remain far enough from the throw-off point to obtain momentum to make the pick-up. The cable must be dropped only at points designated by the sign "Drop cable here." Dropping the cable before reaching the sign injures the cable.

59. In passing from one cable to another, trains must pass over pick-ups at slow speed, and before taking hold of the auxiliary cable, the train must be brought almost to a stop. The grip driver must be careful when passing over pick-ups to move the train slowly until the last car has passed the curve in the track, to avoid jerking the car sideways.

60. If the grip misses the cable, examine the grip, and if it is in good order, put the cable in with hooks. Never pull the grip car back or forward attempting to catch the cable. If the grip is out of order, take it out at the grip trap and have the train pushed in by the next train. Never allow a broken grip to pass a let-go sheave.

61. When the cable is thrown into the grip with hooks, the grip must be examined at the first manhole. The driver must know positively that the cable is on the right side of the grip.

62. Whenever the cable stops running, the driver must immediately loosen the hold on the cable, and in no case take hold again until the cable is well in motion.

63. In case the cable is moved backward, the driver must open the grip and allow the cable to pass through, but not throw it out or take hold again until the cable has attained regular speed in the forward motion.

64. When approaching the track on which employes are at work, the driver must sound the gong, have the train under perfect control, and keep a sharp lookout.

65 Special care must be taken in the case of employes in or about manholes.

66. The grip driver must be thoroughly familiar with the construction and operation of the grip and brakes.

Special for Motor Drivers.

67. When cars are standing in the house, the motor should be cut out of the safety switch.

68. When examining the motor with the trap door open and the car in motion, face the rear of the car to avoid being thrown upon the motor should the car suddenly stop Be careful when bending over motors, that nothing slips from the pockets into the machine, and that no water drips from off your hat or clothes.

69. Do not allow any metal—for example, an oil can—to touch the brass screws on the motor boards unless the trolley wheel is off, or your person touches nothing but dry wood.

70. If the trolley wheel comes off, the car will suddenly let up and at night the lights will go out. Stop the car immediately.

71. Cross railroads and all frogs and switches at the speed of a horse walk. Remember there is a switch in the trolley wire, and wait until the trolley wheel has passed the same and you have the signal from the conductor before turning on the current. Do not pass other cars on curves; the car on the inside has the right of way.

72. In case a motor flashes, has a burning smell about it, or in any way goes wrong, it can be cut out with a key hanging in the car. Insert the key in the socket with the pointer up, and turn the pointer around one quarter of a circle towards the good motor. Never attempt to turn this cut-out switch unless the car switch is off.

73. Do not run over any stick, stones, spikes or wire that is liable to get caught or knocked up against the motors. Stop the motor and let the conductor pick up the obstruction and bring it home on the car.

74. In case of a thunder and lightning storm, the motor driver must not get excited, for there is absolutely no danger. If the motors are materially damaged by lightning, the car will run unsteadily or stop suddenly, accompanied by a burning smell, or, perhaps, some little noise. If it can be determined at once which motor it is, pull the trolley wheel off, then cut that motor out. If not, pull the trolley wheel off and tie it down, and get pushed

to the shop. Turn on the lamp circuit during a thunder storm.

75. Never dally in the movement of the switch handle. Move on slowly, but strongly and confidently, from step to step, allowing the car to gather headway and respond to each step. In case the switch turns hard, move the pointer to the notch by a succession of slight taps; this will prevent you from shooting over the notch. In case you do run over the notch one third, move on to the next notch. In throwing off, skip the fourth notch. In case (in throwing off) you run over one third of a space, go back to the last one passed. The best notches in throwing off are from five to three, and from three "off."

76. Throw the pointer from the first notch to "off" with a snap. Do not throw the pointer off too soon after starting; allow the motors to gain a little headway, say, five to eight feet.

77. If you leave the switch for a moment take the handle with you; otherwise leave it on the seat of the car.

78. Never throw the switch on the fifth notch if the car does not start on the preceding ones.

79. Never run the car faster than one pole in from five to six seconds under any circumstances.

80. Never apply the brake when the switch is turned on.

81. Familiarize yourself with the sounds made by the car, and if any peculiar sound is noticed use every effort to find its cause and report it.

82. The motor driver, upon approaching a rough piece of track, crossing, switch, curve or broken insulator, must call the conductor's attention by the ringing of two bells, to which he will respond in a like manner at once and watch the trolley wheel.

83. The driver and the conductor must see that the gate straps are closed, except the outside gate of the rear platform.

84. Whenever it is necessary to go beyond the fourth notch to make the time, pass slowly to the seventh, never stopping on the fifth or sixth, and always use the seventh notch on grades. Of the lower notches, the third should be used in preference to the first, second or fourth.

85. The driver must shut off the current when the trolley is passing the trolley brake.

86. The driver must be careful in the use of sand on the track, as too much will prevent ground connection. A small amount will prevent the wheel from slipping.

87. Never, under any circumstances, run down grade with the current on.

88. Always have the trolley in contact with the line when the car is going down grade, for the brake might fail, and it might be necessary to reverse.

89. Prepare for heavy grades by throwing the switch on to the fifth and last notch when the car is going its fastest at the foot of the grade. During wet weather, however, if the car wheels slip while on the grade, work the switch back to the fourth point, or even work it back to the first point and "off" point until the wheels get a grip, then work up gradually to the seventh notch. Do not stop on grades where the car will not easily start again, and in no case upon curves, except to avoid accidents.

90. Always move the switch handle in the same direction as the hands of a watch, and never in the opposite, except when it is necessary to reverse the motors.

91. When starting the car, throw the switch handle from "off" to the first notch, pause, and then move to the second, etc. Do not throw it suddenly from "off" to second.

92. If there is no evidence of current, notice the other cars; if they are all right the trouble is in your car. Examine the brushes to see that they are not broken and that they make good contact. In case the car is on a dirty rail, take a piece of insulated wire and make a good connection between the wheel and the rail. The rail may be "dead;" so in this case make some connection between the wheel and the next nearest rail. Be careful to break contact with the wheel first, otherwise a shock will be received. Work both switches, and if one works, the trouble is probably due to poor contact in the other. If neither switch works, ascertain whether the fuse has been blown. If the fuse is

blown, remove the trolley from the line before putting in a new one. Throw on the lamp circuit. If the lamps light up, the trolley and ground wires are all right. Throw on the switch, and if the lights go down, the trouble is probably due to poor rail connection. Sometimes the car will not start on one notch one way, but will on the corresponding reverse position; the trouble in this case is due to poor contact; so bring the handle to the "off" position, remove the cover and work the contacts.

93. Never reverse the switch except in cases of extreme necessity, such as avoiding a collision and running over a human being. If there is time, apply the brake, and then reverse slowly to first point, it not, reverse instantly and apply the brake vigorously at the same time, but let it fly off as soon as the car begins to move backward. Reversing is a severe strain on the apparatus, especially when the car is under high speed, and should not be resorted to except when absolutely necessary.

94. If any sparking is noticed at the joints ahead, or if the car suddenly gathers speed after passing a joint, it is due to a broken or loose connection between the rails. Matters of this kind should always be reported promptly.

95. The armature, field coils, diverter coils and commutator should never get so hot that it is impossible to hold the hand on them. Never try to run a motor that is seriously out of order, as it is liable to greatly increase the trouble.

96. If for any reason the current is shut off from the line, causing a general stoppage of cars, care must be exercised to prevent all the cars from attempting to start at the same time after the current is renewed. After the current is renewed, as indicated by the lamp circuit, cars must be started by divisions in the following order: First half minute after current is on all cars on the first division. Second half minute (or one minute after current is on), all cars on the second division, and so on for each division.

SPEED AND HEADWAY.

See rules 85–88 for conductors.

97. The driver must walk his horses going on or off turnouts, and around sharp curves, and drive at a moderate pace when passing a car on parallel track, or down steep grades, whether behind time or not, and must see that all switches are properly adjusted before attempting to drive over them.

98. The driver must pay particular attention to braking up when approaching vehicles upon the track, allowing sufficient room for them to get out of the way should the wheels slide.

99. At any time when the street is blocked, the car must be stopped before arriving at the place, and an open space between car and block must be preserved, for carriages to pass.

100. Cars driven in the same direction must not approach within a distance of fifty feet, except at stations and turnouts and to avoid accidents.

Special for Grip Drivers.

101. While running, keep 300 ft. from the preceding car except at the end of the route or in case of a disabled car or blockade. When standing at railroad crossings and stations have at least one foot between cars. Never block a cross street by running up to a standing car or team.

102. When two or more trains are running within a short distance of each other, and the last train is not followed within several blocks by another, then the last two trains must equalize the distance and fall back.

103. In taking curves, slow up before entering, then put on the grip and pull through steadily. Never take a curve at full speed except on steep up grades.

104. In running over switches, cross tracks, castings and the vaults, run slowly, except when greater speed is necessary at pick-ups.

105. The grip drivers must not move a train at a greater speed than four miles per hour while passing trains standing on the opposite track, which are delayed by a blockade or resting at the end of the route.

TREATMENT OF PASSENGERS.

See rules 59–70 for conductors.

106. The only persons authorized to ride in the cab with the gripman are: The president, the superintendent, the chief engineer, the assistant superintendents, the day roadmaster, the night road-

master, the superintendent of machinery and the chief gripman. Under no circumstances will others than the above be allowed to ride in the cab without orders from the superintendent.

107. When running under four bells, politely notify persons wishing to ride to take the next car (or train).

CARE OF CAR AND FURNITURE.

108. It will be the duty of the driver to keep the outside of the car clean and to assist in putting the car back in the car shed. He must hand over the stock on the last trip to the proper person, or place them in their stables, removing the harness and safely tying them before leaving.

110. It is the driver's duty to examine carefully the brakes on the car, the harness and the shoes of his horses before starting on any trip, and to report any repairs that are necessary.

111. The driver must assist, if necessary, in taking cars out of the car house and in putting them away.

Special for Grip Drivers.

112. Keep the grip well shod. Grip drivers on day trains must see that the shoes are in good order before turning the car over to the swing driver. Avoid shoeing the grip between the hours of four and six P. M. as cars are on short headway, and such delay would cause cars to start irregularly from the stations.

113. The driver must never, under any circumstances, take out a train that is not provided with automatic brake, safety chains and all other safety appliances in good working order and condition. Make a thorough examination and see that links and pins are in place and the grip car safely coupled to the coach. Oil the brakes and bearings, and never start or run your train if not provided with a wrench, hammer and other tools, oil can and pin, which must be procured at the office and kept in the place provided for them, and properly accounted for

114. Each car when running after dusk, or in the morning before daylight, must display a white headlight. The driver most see that the headlight is placed in position at the proper time and kept burning, but neither too high nor too low. See that the number corresponds with that of the car you are running, and return them to the lamp room when not required.

115. Each driver must keep the grip car in thorough cleanliness and in tidy condition at all times. He must keep the centre lamp clean and be careful not to allow it or the headlight to smoke. Waste and brooms used in cleaning the car must be kept out of sight. As soon as a lamp begins to leak, it must be taken out of the car.

COLLECTION OF FARES AND CHANGE.

116. See Rules 40–43 for conductors.

Special for Drivers of Conductorless Cars.

117. If fares are not paid within one block after passengers enter the car, the driver must call the person's attention by ringing the bell in the fare box. If it then becomes necessary, he must stop the car and demand the fare in person, but always in a polite manner, as "Your fare, please." If received it must be dropped into the box before starting the car; if not, he must ask the person to leave the car.

118. The driver must ring the register for every passenger as he takes the car, and not as he pays his fare, and "dump" the fares into the cash drawer as soon as deposited by the passengers.

PARCELS AND FREIGHT.

119. The driver must not carry any message or package unless instructed so to do by some one in authority.

120. The driver must not allow on the front platform any large package or article that will interfere with the performance of his duties.

LOST ARTICLES.

121. All articles found by the driver in the car must be at once handed to the conductor.

See rules 110–111 for conductors.

TRANSFERS.

122. See rules 56–58 for conductors.

STOPPING.

123. Except in cases of emergency, brake up gradually, so as not to throw standing passengers. When stopping, release the brake a little so as to

make an easy stop. Never slide the wheel if it is possible to avoid it.

124. The driver must not stop upon grades when, in his judgment, the car cannot easily start again, and in no case upon curves, except to avoid accidents.

125. In stopping at the usual places the driver must apply the brake in such a manner as will gradually bring the train to a stop and avoid all jerking and surging. All trains must be stopped in such a manner that the rear car shall not obstruct the cross street.

126. Unusual care is enjoined when passing a stationary car, especially at a street crossing. No train must be run past a standing train at a greater speed than four miles per hour, and the gong must invariably be rung from the time the moving train is within fifty feet of the front end of the standing train.

CROSSINGS AND SWITCHES.

127. Cars must be stopped at the farther crossing of all intersecting streets, and in such a manner as not to wholly obstruct such crossing.

128. The driver must have the train under complete control in approaching any steam or street railway crossing, and must not run the train at a greater speed than four miles per hour for at least seventy-five feet approaching a crossing, and until it has fully passed.

129. The driver must not approach a steam railroad crossing nearer than fifty feet before bringing the train to a full stop, and must await the conductor's signal from the railroad crossing to advance.

130. The driver must not recognize the signals of railroad flagmen or conductors of other trains, but if warned not to cross by the flagman he must hold the train until the danger is passed.

131. The driver must slacken speed when crossing prominent streets. When passing another train on a cross street both trains must reduce speed, and special care must be taken to avoid accidents.

132. Whenever a conductor has to go forward to signal the car (or train) over a railroad crossing, to change a switch, or for any other purpose, the driver must look back and see that all passengers are safely on and off the car before attempting to start.

RIGHT OF WAY.

133. See rules 93–98 for conductors.

FIRE DEPARTMENT.

134. When vehicles of the fire department are in the street running to a fire, the right of way must be given them as far as possible. Stop the car (or train) until the vehicles have passed.

135. When a hose is laid across the track do not approach nearer than 100 ft., unless the hose bridges have been properly placed over it. See rule 109 for conductors.

ACCIDENTS.

136. Whenever an accident of any kind happens to or is caused by a car, the driver must stop at once and assist the conductor in ascertaining the nature and extent of the injury and the full particulars, and in case of a serious personal injury, he must render all the assistance possible.

137. A driver of a conductorless car must be governed in case of accident by rules 99–104 for conductors.

138. When the car is in motion, the responsibility for safe running rests with the driver. Appliances are furnished for controlling the car quickly, and accidents can and must be avoided. Vigilance, the exercise of good judgment, avoiding risks, and a strict compliance with rules and orders, will prevent accidents.

POLICE ASSISTANCE.

139. See rule 108 for conductors.

BLOCKADE.

140. A driver must speak pleasantly to teamsters or any other persons who may be in the way, requesting them to move. In case the driver of any vehicle refuses to pull out of the track, and persists in driving slowly, or otherwise obstructing the passage of the car, notify the conductor, that he may call upon a policeman to compel such driver to turn out.

141. When a team is standing alongside of the track, with the wagon pole or horses standing with

their heads toward the track, with a possibility of rubbing the car, ring for the conductor to go forward to pull the horses out of the way. See rules 105–107 for conductors.

TIME.

142. The driver must have the car ready to leave the car house promptly on time.

143. The driver must regulate the speed of the car so as to be as nearly uniform with the time card as possible, and not lose time on one portion of the route and make it up on another. If he should unavoidably get behind time, it is not to be made up in the next two or three blocks by a spurt, but gradually, by driving (running) slightly faster. See rules 118–121 for conductors.

TRACKS.

144. See rule 122 for conductors.

Special for Grip Drivers.

145. Should it be discovered that a manhole cover is missing or displaced, the fact must be reported on a blank supplied for the purpose to all grip drivers; this applies to any loose stones in paving, injury to slot or track.

146. Notice must also be given to any employes who may be met near the spot, who must at once proceed to the point and guard it if it is not in their power to repair it.

147. If a driver should discover any defect in the paving or track, it is his duty to inform the conductor, who must report it at the office.

TRIP REPORTS.

148. At the close of each day's work the driver must fill out a proper blank and hand to the receiver a report of the number of the car and the number of trips run by him during the day.

PENALTIES.

149. See rule 127 for conductors.

RESPONSIBILITY.

150. The driver will be held responsible to the company for all damages caused by neglect of duty, or carelessness on his part to their property, or to the person or property of others, for which the company may be held responsible or liable.

151. Any driver who, upon leaving the service of the company, shall fail or refuse to return to the company all of the uniform buttons which have been furnished him, will be charged for all buttons which he shall fail, or refuse, to return.

152. In case a driver shall lose any of these buttons while in the service of the company, he is required to draw other buttons to take their place and will be charged therefor.

153. Ignorance of the rules will not be accepted as an excuse for not observing them.

RESIGNATION.

154. See rule 126 for conductors.

DISCRETION.

155. In all matters not fully covered by these rules, the driver is expected to use judgment, common sense and discretion in performing his duties and dealing with passengers and any others with whom his duties call him to deal.

RULES FOR HILLMEN AND TOW BOYS.

Rule 1. A hillman must attend punctually at his proper station, get to his work promptly, attend to it faithfully, and not leave until the time set.

2. Before starting, each hillman must see that his horse is properly shod, and that the harness is in proper condition to work.

3. He must not pull, yank, strike, kick or otherwise abuse a horse, or carry a whip or any substitute therefor without the consent of the foreman of the stable.

4. He must not hold unnecessary conversation with the car driver or any other person.

5. He must drive his horse up and down the hill, keep out of the way of teams as much as possible, and stand his horse in the least objectionable places.

6. He must take his horse to and from work at a slow pace, and if riding it must not go out of a walk or a very slow trot.

7. He must not hitch on or take off his horse while the car is in motion, or so as to obstruct any crossing or endanger passing thereon.

8. He must deport himself in a proper manner

at all times, use no boisterous, obscene or profane language, and avoid all associations which will interfere with his work or the proper performance of his duty in all respects.

Special for Storage Battery Cars.

ON THE ROAD.

RULE 1. Always carry: Two cell jumpers, one sparking wire, one heavy connector wire, one sheet of coarse sandpaper, one sheet of fine sandpaper or emery cloth, one piece of narrow board, four extra cell connectors, two strips of lead, six little lead squares, one extra incandescent lamp, six extra brush carbons, two candles and matches, one monkey wrench, one screw driver, one pair of pliers, one can full of oil, one coupling bar, one track iron, waste and dry rag or chamois.

2. In starting, move the regulator handle quickly to the first notch and hold it there a while until the car has gained some headway; then move it on to the other notches, as required. If the car fails to start on the first notch, let the car gain some headway on the second notch before putting on the full power, except when necessity demands it.

In turning off the current, throw the regulator handle clear over with a quick movement. If the regulator switch is out of order and the spark continues to burn after the circuit is broken, throw the reverser into the off position at once.

3. Never attempt to put on the brake when the current is on the motor; always pull the regulator handle back to the off position and then apply the brake. Govern the speed of the car with the regulator, not with the brake. You are not driving a mule.

4. Do not turn the reverser when the current is on the motor. Throw back the regulator handle, turn the reverser, and then put on the current.

5. In case the batteries become weak or there is trouble with the machinery, or the car is already overloaded, it will be better to stop only to let off passengers and not to stop to take any on.

6. If a brush has been sparking excessively or is wearing grooves in the commutator, or the commutator is rough or dirty, put in a new brush and sandpaper the commutator to a smooth surface

TROUBLE.

7. Should the motor stop:

(*a*) Turn on the tell-tale lamp in the regulator box, or the electric lamp in the centre of the car. If the lamp burns, the trouble is not in the cells on the right hand side of the car as you face the front doorway. If the front headlight burns, the trouble is not in the cells on the left hand side of the car. If the headlight is not on, touch the posts, where the headlight connections are made, with the sparking wire; if there is no spark the trouble is under the left hand seats. If the centre or tell-tale lamp fails to burn, the trouble is in the left hand battery. If either lamp fails to burn, overhaul the batteries carefully for loose connections, bad contacts, burned off terminals and other faults.

If no fault is visible, test by short circuiting each cell quickly with the sparking wire until the faulty cell is located. Do not stop to investigate the nature of the trouble, but disconnect both terminals of the cell and bridge over the break with a jumper. In working around the batteries be very careful not to make any metal contact across the cells in the tray. If this is done a destructive short circuit will result.

(*b*) If both lamps burn, the trouble is not in the battery connections. Look for the trouble at the motor brushes and the connections or in the switch boxes. See if the brushes are in firm contact with the commutator; that the connections to the brush holders and the motor are complete and tight; that two or more wires are not touching through their insulation, or in contact with the metal parts of the motor or the car, and that the armature and fields of the motor are not burned out. If the fault is due to defective contact of the brushes, the appearance of the commutator or brush will often be the means of immediately locating the trouble. Sandpaper the commutator and adjust and put in a new set of brushes, if necessary.

(*c*) If the motor and its connections seem all right, examine the regulator and the reverser and their connections for loose wires, damaged contacts, etc.

(*d*) If the regulator is out of order and fails to

work, connect the wire provided for that purpose to wire No. B, and run the car by successively making contacts with wires numbered 1, 2 and 3.

(*e*) If the reverser is out of order and fails to work, disconnect wire No. 7 and connect No. 7 to No. 8 to go ahead, and No. 7 to No. 9 to back.

(*f*) If the switches get stuck with the current on, immediately break the circuit by disconnecting wire No. 7 at the reverser, or break the connection in the batteries under the seats.

(*g*) The difficulty may be of a mechanical nature. See if the bearings of the motor and the gearings are hot, and whether the armature or the gears have stuck fast or jammed. These latter may be discovered by starting the car ahead and then back, noting the behavior of the motor and the gearing each time. (Keep the current on for only such a length of time as is absolutely necessary for these tests.) Cool down any hot bearings and remedy the trouble to the best of your ability.

(*h*) If the tests given above fail to discover any defect, the car must be pushed or pulled to the station.

WARNINGS AND NOTICES TO PASSENGERS.

Opinions differ as to the advisability or necessity of posting notices of any kind inside street cars. When new lines are started there is some advantage in having notices posted until patrons become familiar with the rules and regulations, after which they may be removed. There is a growing tendency in large cities to omit all notices of this kind. The laws of some states, and of certain cities, require that warning notices and rates of fare be posted in all street cars, leaving in this respect no discretion on the part of the companies. Warning notices are considered useful in that they show to the patrons that the company is using its best endeavors to prevent accidents, and that contributory negligence may be rightly urged against violators. In case of accident trials, however, the courts hold, usually, that cautionary or warning notices do not exempt a company from paying damages, provided it is shown that the employes of the company are in any manner to blame.

In case notices are employed, it is better to word them in the form of a polite request or caution, rather than in the form of an arbitrary command. It weakens the force of a rule to state it arbitrarily with "must" or "forbid," where its violation cannot be followed by a penalty. Rules to drivers and conductors should be in the imperative form, but not those to passengers. For instance: A notice like the following, "Spitting in this car positively forbidden" could not be enforced, for the passenger might spit out at the window or the door, or might use the coal box or even his handkerchief, or if, from necessity, he should spit on the floor, the chances are that the conductor would not see him, and if he did he would not be likely to order him off the car. Some people are so constituted that, seeing a rule like the above, they would instinctively violate it to show their independence. It is better to say, in case such a notice is found to be necessary, "Gentlemen; please do not spit on the floor of this car."

The following notices are copied from the practice of several roads in widely separated localities. These are not given as models to be followed in all cases, but they will be found to be suggestive, and may be modified to suit local conditions, and to conform to the above hints, in case it is desirable to post notices of this character in the cars. In case notices are posted, they should be printed in plain type on heavy cardboard, and carefully framed with glass to exclude dust; and in no case should they be allowed to become disfigured or faded from age, but should be renewed as often as is necessary to keep them bright and clean.

(1.)

Passengers will please put fare in the box.

Gripmen on duty must not engage in conversation.

(2.)

Passengers must not get on or off the car while it is in motion; it is dangerous.

Gentlemen: Please do not spit on the floor of this car.

(3.)

NOTICE.

Passengers are requested not to converse with ıe driver or divert his attention from his work.

....., Supt.

(4.)

NOTICE.

On and after May 5, 1891, NEWSBOYS will not be ›ermitted to get on the cars of this company for he purpose of selling papers.

(5.)

Conductors must register all fares except trans-ers. Children occupying seats full fares.

Transfers will be issued to passengers at the fol-lowing points:

(6.)

NOTICE TO PASSENGERS.

This car has a step from the platform into the car. Upon entering or leaving the car

BEAR THE FACT OF THIS STEP IN MIND.

(7.)

NOTICE TO PASSENGERS.

Children under four years of age, not occupying seats, carried free—No half fare.

Transfer tickets, good only for one continuous ride, are issued without extra charge.

(8.)

This car will stop to receive and let on passengers, only at farther crossings of street intersections, and in the middle of long blocks where the sign is placed.

By order of the City Council, July 17, 1882.

....Railway Co.

(9.)

Passengers will please put their fare in the box, as the driver is not allowed to either receive or deposit it.

Put only the exact fare in the box.

No one allowed to ride free.

Passengers will pay their fare on entering the car.

(10.)

NOTICE TO PASSENGERS.

Passengers must not get on or off this car without signalling the conductor to stop.

All persons getting on or off cars in motion, riding on platforms or steps, do so at their peril.

Straps and railings are provided for security, particularly on curves.

(11.)

Please do not stand on the rear platform, but give passengers a chance to get on and off safely.

Passengers are not allowed to get on and off the cars between the double tracks.

Rates of fare.

Smoking not allowed on the rear platform.

Please do not spit on the floor of this car.

(12.)

Passengers on leaving the cars must alight on the side nearest the sidewalk.

Transfers are used only on condition of immediate use at the time and place designated thereon, of which passengers must take notice; ask for transfers when you pay your fare.

Do not get off the car while it is in motion.

(13.)

FARES AND TICKETS.

All passengers twelve years of age or over will pay five cents cash or full fare ticket.

All passengers between five and twelve years of age will pay three cents cash or half fare ticket.

Twenty-five full fare tickets $1.00, or six for twenty-five cents.

Twenty half fare tickets fifty cents.

(14.)

All persons are warned not to enter or leave this car while it is in motion, or by the front platform.

No disorderly or otherwise obnoxious person, whether or not under the influence of liquor, will be allowed to ride upon this car.

Notify the conductor when you wish to leave the car.

Do not leave the car while it is in motion.

(15.)

These cars stop at farther crossings only.

Passengers are particularly cautioned not to get on or off the cars while the cars are in motion or to stand on the running foot boards.

Passengers are requested to get on and off the *rear* platform only

Children over five years old will pay full fare.

Children under five years, when occupying seats, will pay full fare.

(16.)

PASSENGERS ARE NOTIFIED THAT IT IS DANGEROUS:

To ride upon the platforms;

To get on or off the car while it is in motion;

To leave the car by the side next the adjoining track.

Those violating these warnings do so at their own risk.

Passengers will please report any impropriety or neglect on the part of any conductor or driver.

(17.)

RULES FOR PASSENGERS.

All persons getting on or off the cars must first notify the conductor, then wait until the car stops in response to the conductor's signal before attempting to get on or off the cars.

Cars stop only on the conductor's signal, to receive and discharge passengers on the far side of all street intersections.

Passengers are prohibited from riding elsewhere on the cars than on the inside.

All persons are notified that they violate any of the above rules at their own risk.

(18.)

To prevent accidents: Do not get on or off the car until it stops.

Do not stand upon the steps.

Look out for passing vehicles when alighting.

Small luggage only will be taken upon the cars of this company ; any excess will be charged for.

Full fare will be collected for children five years of age and over, and for younger children when occupying seats required by other passengers.

When two or more children between two and a half and five years of age are together, fare will be collected at the rate of one fare for two children.

(19.)

Passengers are requested not to spit on the floor of the car.

Children over five years of age, full fare.

Under five years, accompanied by parents or nurses, FREE.

All cars on the above route will stop at the farther cross walks unless otherwise specified, but only upon request of a passenger wishing to board or leave the car.

Passengers are notified that the conductor will call the names of streets on each trip. When passengers desire to get off the car, they must notify the conductor before arriving at their destination. Stops will not be made at any point where passengers do not desire to get on or off the cars.

(20.)

PASSENGERS ARE NOTIFIED:

1. To take hold of the hand rail in getting on or off the car ; to enter and pass out on the side of the car nearest the sidewalk ; not to enter or leave the car until it is fully stopped, and not to get on or off the front platform.

2. No person intoxicated, or otherwise violating public decency, will be allowed on the cars.

3. All bundles or packages carried will be held in the hands or on the lap of the passenger, or placed under the seat.

4. Gentlemen will please not smoke (except on the front platform when the front doors and windows are closed) ; and will not spit on the floor or put their feet on the seats of the car.

....., Supt.

(21.)

PASSENGERS may take this car at any point without additional fare.

No cumbersome or offensive packages or bundles will be carried.

Fare will be collected from all except children in arms. No one allowed to ride free.

Please do not address unnecessary conversation to the conductor or motorman, diverting their attention from their duties. THE FARE ON ALL NIGHT CARS WILL BE TEN CENTS AFTER MIDNIGHT.

PASSENGERS MUST NOT STAND HERE.

SPITTING IN THIS CAR POSITIVELY FORBIDDEN.

By order of

....., President.

....., Supt.

Signed by ....., Supt.

(22.)

NOTICE TO PASSENGERS.

Passengers are not allowed to get on or off the cars while the cars are in motion, or to stand on the steps.

Passengers are particularly requested not to put their heads or arms out of the window, or to get on or off or ride on the front platform, as the company will not be responsible for accidents that may occur by reason of so doing. The cars will stop on the down corner going down, and the up corner going up, as required by law, and passengers are particularly requested to get off from the right hand side of the car, which is nearer the sidewalk.

Children over five years of age will be charged full fare; those under five years with parents or guardians will be carried free.

The company will be pleased to have passengers report any negligence or inattention on the part of the conductor or driver.

(23.)

Fare, five cents. No half fares are received, and no one is allowed to ride free EXCEPT children under five years of age, NOT OCCUPYING SEATS which may be required. A charge of ten cents will be made for all PACKAGES too bulky to be carried in the lap or placed under the seat. TRUNKS, FIFTEEN CENTS.

CONDUCTORS ARE REQUIRED TO RING THE "INDICATOR" FOR EVERY FARE COLLECTED.

PASSENGERS ARE SPECIALLY NOTIFIED that this company will not be responsible for accidents occurring under violations of the following rules, viz:

That they must not get on or off, or occupy the front platform of any car, or get on or off a car when it is in motion.

That they must not occupy the rear platform when there is accommodation inside, or stand or sit upon the steps of any car.

That they must not put their heads or arms upon or out of the windows, or enter or leave a car except at the right hand side of the rear platform.

THE PRESIDENT WILL GLADLY RECEIVE INFORMATION OF ANY IMPROPRIETY COMMITTED BY EMPLOYES, OR OF ANY NEGLECT OR VIOLATION OF THESE REGULATIONS.

(24)

TO OUR PATRONS:

SAFETY AND RAPID TRANSIT.

To meet the demand for rapid transit and safety, it becomes necessary that our patrons assist therein by a strict compliance with the following rules:

First. Cars will stop only at the farther crossing of the intersecting streets.

Second. Be at that point in readiness to signal and board the car with the least possible delay.

Third. Notify the conductor when he calls the street at which you wish to leave the car, and be in readiness at the rear door to alight as soon as the car comes to a full stop.

Fourth. Get on and off the rear platform and upon the curb side, or the right hand side of the direction in which the car is going.

Fifth. Do not stand upon the platform while there is room inside.

Sixth. In boarding or leaving a car do not attempt to cross the street immediately in front of a car approaching from either direction.

Seventh. Do not attempt to board or leave a car without notifying the conductor.

Eighth. Complaints of any character must be made over the signature of the complainant. No attention is paid to anonymous letters.

CHAPTER X.

CHARTER—FRANCHISE—STOCKS AND BONDS.

Having studied the mechanical features of the various types of street railways, we have now to consider the requirements and powers necessary for the complete equipment of the company or corporation for the transaction of its business. The aim of this chapter is: First, to furnish parties engaged or interested in the line of street railway business a guide or assistant in the organization of new corporations, the consolidation of existing companies, and charter amendments; second, to define the legal and commercial terms that are used in the business, so that the internal affairs of a company may be readily understood by the average stockholder; and third, to name some of the special requirements that are imposed by state and municipal authorities in the granting of charters and franchises, so that any company may be able to determine, by comparison, the value of the concessions it has received, and the justice or injustice of the special requirements and restrictions to which it is subjected.

It is not our intention in this chapter to invade the province of the legal profession, and give a code and standard forms that can be used without legal advice, any more than we have assumed the duties of the engineer in preparing the mechanical chapters. We shall try, however, to illustrate and describe some of the elementary and essential features of certain legal forms, so that a common ground may be formed upon which the layman may be able to intelligently discuss the business affairs of a company with its legal representative, and to read and understand the financial reports.

The method of organizing a railroad corporation, and the laws relating to the same, differ widely in the different states; so that were we to copy all the different forms in use and compile the various state enactments, this chapter would expand to the volume of an ordinary law book. Manifestly, this cannot be done, but let us hope the time will come when all the state statutes relating to street railway subjects shall be revised and consolidated into a uniform and harmonious practice.

A charter may exist in fact or only in name. In some states the filing of the articles of agreement with the clerk of the county and with the secretary of state is presumptive evidence of the incorporation, while in others the governor issues a patent or charter after articles have been filed. Some states have enacted a general corporation law under which all corporate bodies are organized, while in others a special act is passed in each case. In a few cases the legislature first appoints a commission to open books, receive subscriptions and organize a company, the commissioners themselves being permitted to become members of the corporation. In one state, at least, which has enacted a general corporation law, a commission is appointed to organize a company and determine routes for railroads in cities, other than surface roads, while in most cases the parties desiring to form a corporation take the initiative on their own account and afterwards file their articles of agreement.

A corporate charter is a contract between three parties, viz., the state, the corporation and the stockholders. First, it is a contract between the state and corporation (an artificial person); second, it is a contract between the corporation and the stockholders; and third, it is a contract between the stockholder and the state. As between the state and the stockholder, the contract is protected by that provision of the United States constitution which prohibits a state from passing any law which will impair the obligation of a contract. A charter may be perpetual or limited, and, if limited, may contain provision for an extension. In some cases

a charter may be extended by filing application, as in the first instance. In some states the legislature reserves the right to alter, amend or repeal the charter at any session.

The reservations, however, are generally for the protection of the state's interest and not for the benefit of the corporation or individual.

A state tax for the privilege of organization is usually imposed upon corporations having capital stock divided into shares, which tax is due and payable before the certificate of incorporation or articles are filed. A like tax is also required in some cases upon an increase of capital stock. Besides the taxes a fee is demanded for filing the certificate in the office of the secretary of state, and a fee of — cents per folio for recording in both the county and state records.

The following are some of the provisions of a general act, quoted from the laws of New York State relating to the organization of railway corporations:

INCORPORATION. Fifteen or more persons may become a corporation, for the purpose of building, maintaining and operating a railroad, or of maintaining and operating a railroad already built, not owned by a railroad corporation, or for both purposes, by executing, acknowledging and filing a certificate, in which shall be stated:

1. The name of the corporation.
2. The number of years it is to continue.
3. The kind of road to be built or operated.
4. Its length and termini.
5. The name of each county in which any part of it is to be located.
6. The amount of the capital stock, which shall not be less than $10,000 for every mile of road built or proposed to be built, except a narrow gauge road, when it shall not be less than $3,000 for every such mile.
7. The number of shares into which the capital stock is to be divided.
8. If the capital stock is to consist of common and preferred stock, the amount of each class and the rights and privileges of the latter over the former.
9. The names and post office addresses of the directors of the corporation (not less than nine) who shall manage its affairs for the first year.
10. The place where its principal office is to be located.
11. The name and post office address of each subscriber to the certificate and the number of shares of stock he agrees to take.

Such certificate shall have endorsed thereon, or annexed thereto, to be taken as a part thereof, an affidavit of at least three of such directors that at least ten per cent. of the minimum amount of capital stock authorized by law has been subscribed thereto, and at least ten per cent. of such subscription has been paid in cash and in good faith to the directors named in the certificate, and that it is intended in good faith to build, maintain and operate the road mentioned therein. The filing of every certificate, where the amount of stock required by this section has not been in good faith subscribed and ten per cent. thereof paid in cash, shall be void.

FORM OF CERTIFICATE OF INCORPORATION OF A RAILROAD COMPANY UNDER A RAILROAD LAW.

STATE OF.....} ss.
County of.....}

We, the undersigned, desiring to become a corporation under and by virtue of the provisions of "The Railroad Law," for the purpose of building, maintaining and operating a street railroad, hereby certify as follows:

First. The name of the corporation shall be the X. Y. Z. Cross Town & Broomfield Railway Co.

Second. The number of years it is to continue shall be ninety-nine years.

Third. The kind of road to be built shall be a street surface road.

Fourth. Such railroad is to be built, maintained and operated from the city of X.Y.Z. to the township of West X.Y.Z., which places will be its termini, and its length will be ten miles.

Fifth. The counties of E. and O. are the names of each county in which any part of it is to be located.

Sixth. The amount of the capital stock shall be $20,000.

Seventh. The number of shares into which the capital stock is to be divided shall be 400 shares.

Eighth. The capital stock shall consist of 300 shares of common stock and 100 shares of preferred stock, and the latter shall be entitled to a two per cent. dividend out of the net earnings before a dividend shall be declared on the former.

Ninth. The names and post office addresses of the directors of the corporation who shall manage its affairs for the first year are as follows, namely:

NAME.	P. O. ADDRESS.
1. John H. Robertson	New York.
2. C. D. Wyman	" "
3. D. B. Hasbrouck	" "
4. Geo. W. Linch	" "
5. Fred. F. White	" "
6. J. E. Rugg	" "
7. Thomas H. McLean	" "
8. John N. Partridge	Brooklyn, N. Y.
9. Wm. J. Richardson	" "

Tenth. The place where its principal office is to be located is the city of X. Y. Z. county of O.

Eleventh. The name and post office address of each subscriber, and the number of shares of stock he agrees to take in such corporation are subscribed to this certificate.

In witness whereof, we have executed and acknowledged this certificate in duplicate, and have hereunto subscribed our respective names, post office addresses, and the number of shares of stock we severally agree to take in such corporation.

Dated the.....day of....., 186 .

	NAME.	P. O. ADDRESS.	NO. OF SHARES SUBSCRIBED.
1.	John Harris		50 shares.
2.	J. W. McNamara		50 "
3.	John H. Robertson		20 "
4.	Wm. J. Richardson		15 "
5.	G. B. Kerper		25 "
6.	F. M. Eppley		10 "
7.	C. D. Wyman		20 "
8.	C. B. Holmes		25 "
9.	W. A. Smith		40 "
10.	D. B. Hasbrouck		30 "
11.	Thomas Lowry		40 "
12.	John N. Partridge		20 "
13.	H. H. Littell		30 "
14.	Thomas H. McLean		15 "
15.	Henry M. Watson		10 "

STATE OF.....
County of..... } ss.

On this.....day of....., one thousand eight hundred and....., before me personally came [*name all the subscribers*] to me known, and known to be the persons described in and who made and signed the foregoing certificate, and severally duly acknowledged to me that they had made, signed and executed the same for the uses and purposes therein set forth.

.....
Notary Public.
.....County.

STATE OF.....
County of..... } ss.

J. R., C. D. W. and D. B. H., being severally duly sworn, each for himself, deposes and says, that he is a director named in the foregoing certificate of incorporation; that at least $1,000 of capital stock for every mile of road intended to be built has been subscribed thereto that at least ten per cent. of such subscription has been paid in good faith, and in cash, to the directors named in the certificate, and that it is intended in good faith to build, maintain and operate the road mentioned therein.

Severally sworn to before me, this
.....day of.....189

.....
Notary Public,
.....County.

STATE OF.....
Office of the Secretary of State.

I have compared the preceding with the original articles of association of the X. Y. Z. Cross Town & Broomfield Railroad Co. of X. Y. Z., with affidavit and acknowledgment thereto annexed, filed and recorded in this office on the first day of ....., 189 , and hereby certify the same to be a correct transcript therefrom and the whole of said original.

Witness my hand and seal of the Secretary of State, at the City of....., this.....day of....., 189 .

F. D. RUSSELL,
Secretary of State.

In case it is proposed to change a route, the president and secretary of a company are required to make and execute a proper certificate of such alterations or change of route and to file the same certificate in the same manner as the enjoined certificate, together with a survey and map of the proposed changes.

Most state laws provide for the consolidation of corporations operating different lines by mutual agreement. The capital stock and franchise of the two corporations may be merged and consolidated under certain conditions usually carefully stated in the law. Such a consolidation is not regarded as a partnership, but is entirely a new corporation and liable to an organization or franchise tax. The usual form of such agreement is too long to be given in this connection.

Some of the general provisions relating to the construction and operation of street railways quoted from the same state laws as above, are as follows: Before a line can be built, extended or operated, the consent in writing of the owners of one-half in value of the property bounded on the proposed line, must be obtained. This consent must be acknowledged and recorded the same as deeds are.

The following is a form of consent in common use, although not modelled after the laws above quoted:

KNOW ALL MEN BY THESE PRESENTS :

The X. Y. Z. Cross Town & Broomfield Railway Co., a corporation duly organized under the laws of the State of M. N., desires to extend its present railway tracks and business within the township of M., as follows :

Commencing on the X. Y. Z. road at the boundary line between the townships of B. and M. respectively, and running from thence northerly through the centre or side of said X. Y. Z. road to Elm Street in the township of M.

Also * * *

Also * * *

The consent for this extension is requested for the purpose of constructing, maintaining and operating a street railway in the aforesaid streets or portions of streets or highways for the transportation of passengers and their property, pursuant to the statutes in such cases made and provided.

The undersigned respectfully asks that you will grant unto it your written consent, duly executed, to construct, maintain and operate its railway through such streets and highways, or portions of the same, upon which your property fronts, for the uses and purposes hereinbefore expressed.

Very respectfully,

The X. Y. Z Cross Town & Broomfield Railway Co.,

HENRY MARTIN, Pres.

NOW, THEREFORE, I, WM. JONES,

having read the above request, and in consideration of the the sum of one dollar lawful money of the United States to me in hand paid, the receipt whereof is hereby acknowledged, do for myself, my heirs, legal representatives and assigns, consent, covenant and agree that the aforesaid company may extend, construct, maintain and operate its said railway in and through the street or streets or highway fronting on and adjoining my premises ; a description of my property being as follows :

Having a frontage of 134 *ft. on the east side of X. Y. Z. road.*

PROVIDED, however, that the aforesaid railway company will construct, maintain and operate its road or extension or a part thereof within two years from the date hereof ; and further :

PROVIDED, that said company will comply with the statute of this State, as well as with the conditions imposed by the municipal authorities.

IN WITNESS WHEREOF, I have hereunto set my hand and seal this twenty-fifth day of January, one thousand eight hundred and eighty-nine.

Witness

JOHN HOPKINS WILLIAM JONES. (Seal.)

STATE OF.....}
County of.....}

Be it remembered that on the sixteenth day of February, 1889, personally appeared before the subscriber, a Notary Public of the State of....., John Hopkins, who being duly sworn according to law, on his oath, saith that he saw the said William Jones, the within named grantor, sign, seal and deliver the within indenture as his voluntary act and deed, and that he, the said John Hopkins subscribed his name to the same, at the same time as an attesting witness.

Sworn and subscribed before me,

OSCAR MANLEY, JOHN HOPKINS.

Notary Public of State of.....

In case the consent of property owners cannot be obtained, application may be made to any general term of the Supreme Court, in the State of New York, for the appointment of commissioners to determine whether such railroad ought to be constructed, and their determination, after due public hearing, may be taken in lieu of the consent of property owners.

In large cities having a population above a certain figure, the same laws provide that every railroad company during the first five years shall pay annually into the treasury of the city in which the road is located, three per cent. of its gross receipts, and after the expiration of five years a like annual payment of five per cent.

The consent of municipal authorities must also be procured, and application for such consent must be made in writing, and the authorities, before acting thereon, must give public notice when the application will be considered, by advertising in the local papers, at least fourteen days before the first action is taken. In cities having over a certain number of inhabitants the consent of the municipal authorities must contain the condition that the franchise shall be sold at public auction to the bidders who will agree to give the city the largest percentage per annum of the gross receipts of the corporation, with a bond and such sureties as may be required. The bidder in each case to be a duly incorporated railroad corporation of the state and organized to construct and operate a railroad in that particular city.

Regarding the use of the tracks of other roads, the same law provides that for certain purposes and under certain conditions, in all except one city, the cars of one line may be run not to exceed 500 ft. upon the track of another line, by paying such compensation as can be agreed upon.

Steam roads may be crossed by street railway lines by mutual consent. The agreement usually fixes a stated sum which shall be paid annually by the street railway company for such privilege. The following is a form of agreement between street and steam roads securing the privilege of crossing the latter:

THIS AGREEMENT, made on the tenth day of June, A. D., eighteen hundred and eighty-seven, between the A. B. C. & W. Railway Co., hereinafter designated as the A. B. C. Co., of the first part, and the X. Y. Z. Cross Town & Broomfield Railway Co., of the second part, witnesseth:

That the said parties do hereby agree as follows, to wit:

First. The X. Y. Z. Cross Town & Broomfield Railway Co. may lay and maintain their single track street railway across the present track of the A. B. C. Co. or any other track or tracks thereof which may hereafter be built in C Street in the city of X. Y. Z. The word "crossing," whenever it occurs in this contract, shall be held and understood to mean a space of seven feet in width running at right angles to the lines of the said track or tracks.

Second. The X. Y. Z. Cross Town & Broomfield Railway Co. shall pay all the expenses of laying and maintaining the said track in such manner as shall, from time to time, be best adapted to secure safety in its operation, and under the supervision and direction of the A. B. C. Co.; and shall restore to its former condition any such track or tracks of the said A. B. C. Co. displaced in constructing the crossing; work to be commenced within three days after the execution of this contract.

Third. The X. Y. Z. Cross Town & Broomfield Railway Co. will stop all their cars at or before reaching the said crossing for, at least, ten seconds and sufficiently to ascertain if there is any danger in crossing, and will stop no car on the said crossing.

Fourth. The A. B. C. Co. may, if it sees fit, do any reasonable work, construction or repairs to the said crossing which the said X. Y. Z. Cross Town & Broomfield Railway Co. shall fail to do, and which shall be necessary or advisable to be done for the safe operation of the said crossing; and the expenses thereof shall be payable by the X. Y. Z. Cross Town & Broomfield Railway Co. to the A. B. C. Co. on demand.

Fifth. That the X. Y. Z. Cross Town & Broomfield Railway Co. shall pay to the A. B. C. Co. two hundred dollars annually, but in quarterly payments, towards the wages of a competent flagman, during week days, at the crossing of the A. B. C. Co. at C Street, during the night, between the hours of half past seven o'clock and the time of the night when the last car of the X. Y. Z. Cross Town & Broomfield Railway Co. shall cross the tracks of the A. B. C. Co. at C Street. This flagman is the servant of the A. B. C. Co., and not the servant of the X. Y. Z. Cross Town & Broomfield Railway Co.

Sixth. The A. B. C. Co. agrees that whenever the X. Y. Z. Cross Town & Broomfield Railway Co. desires to place electric wires across the tracks of the A. B. C. Co. for the purpose of operating the cars of the X. Y. Z. Cross Town & Broomfield Railway Co. by an electric motor, the A. B. C. Co. will interpose no objection or hindrance thereto, and will, if necessary therefor, change its single gate on each side of the C Street crossing to double gates, so that the operation of the gates will not interfere with said electric wires, but the X. Y. Z. Cross Town & Broomfield Railway Co. is to place and at all times keep and maintain said electric wires at a height of twenty-two feet above the top of the rails of said railroad tracks of the A. B. C. Co.

Seventh. It is mutually agreed that this contract shall not impair or in any way affect any of the legal or equitable rights of either of the said companies as they would exist if this contract had not been made, except so far, and so far only, as each company has agreed herein.

IN WITNESS WHEREOF, each of said corporations has hereunto caused its president to sign the same and affix the corporate seal of said company. All done the day and year first above written.

[SEAL.] THE A. B. C. & W. RAILWAY CO.,
by JOHN BROWN, President.

THE X. Y. Z. CROSS TOWN & BROOMFIELD RAILWAY CO.
Attest, by HENRY MARTIN, President.
WM. JONES, Secretary.

The repair of streets, rates of speed and the removal of ice and snow are usually left for the local authorities to regulate by ordinance or resolution. But in the laws above quoted the state requires every corporation to keep in repair the street between its tracks, the rails of its tracks and two feet in width outside of its track, under the supervision of the local authorities. As to motive power the same laws provide that any surface road may be operated by animal or mechanical power other than locomotive steam power, which may be approved by the state board of railroad commissioners, and consented to by the owners of one-half of the property bounded on the line. The laws above quoted also provide that only one fare of five cents shall be charged for one continuous ride from any point on the line or branch operated by the same corporation. The right is also reserved by the legislature to regulate and reduce the rate of fare on any road.

In some cases also state laws designate the character of the persons to be employed as drivers or conductors or in any other capacity, and require that such employe shall wear a badge which shall indicate his office or employment.

A state board of railroad commissioners has been established by legislative action in several of the states. These commissioners are usually appointed by the governor, and in some cases are paid from funds derived by a special assessment on all railway corporations. In such states every railroad corporation is required to make quarterly and annual reports of their financial condition and details of operation, to the board of railroad commissioners, according to prescribed forms.

The authority of the railroad commissioner over railway corporations, in addition to the particulars already noted regarding a change in motive power, also extends in some cases to designating the type of rail to be used and the adoption of safety appliances.

The municipal regulations relative to street railway corporations or companies differ still more widely than those imposed by state authority, so much so that no standard form of an ordinance granting a franchise can be given.

Franchise and *liberty* are synonymous terms according to Blackstone, but from the restrictions often imposed by municipal authorities one would infer that the element of liberty had been well nigh eliminated from franchises.

The following copy of an ordinance is given, to serve as a basis of comparison and may be regarded as a model, as it contains few unreasonable requirements.

COPY OF ORDINANCE.

AN ORDINANCE RELATING TO THE X. Y. Z. CROSS TOWN & BROOMFIELD RAILWAY COMPANY.

Be it ordained by the Common Council of the City of X. Y. Z., as follows:

Sec. 1. That "The X. Y. Z., Cross Town & Broomfield Railway Co.," a corporation incorporated under a certain act of the Legislature of the State of M. N., entitled "An Act to Provide for the Incorporation of Street Railway Companies and to Regulate the Same," approved April sixth, A D., eighteen hundred and eighty-six, is hereby granted the right to construct, maintain and operate a street railway for the transportation of passengers upon the following described location of the route of its tracks, within the bounds of said city; that is to say, upon the certain route: Beginning at a point on Washington Street on the boundary lines between the City of X. Y. Z. and township of West X. Y. Z., running from thence southeasterly along and through the centre of Washington Street by single track and turnouts into Day Street in the City of X. Y. Z.

Also, continuing southwesterly along and through the centre of Day Street by single track and turnouts to M. Street in the City of X. Y. Z.

Also, continue across M. Street and across the tracks of the A. & X. Y. Z. Horse Car Railroad by single track and turnouts to C. Street in the City of X. Y. Z.

Also * * *

Also * * *

Also, continuing southwesterly along and through the centre of Scotland Street by single track and turnout to its present termination at or near Highland Avenue railway station, in the City of X. Y. Z., under and subject to the certain restrictions and regulations hereinafter ordained; the same being such restrictions and regulations as the said Common Council hereby deem and ordain to be required for the public interest and convenience; as well as subject to such further reasonable regulations as may be hereafter ordained by said Council under and by said virtue of the aforesaid act, or as shall be applicable to all of the horse railroads in said city.

Sec. 2. The grant hereby made is under the following restrictions and regulations, to wit:

I. There shall be only a single track laid, and that shall be upon the middle of each street, except where the Common Council shall, by resolution, otherwise expressly determine; but there may be as many turnouts and switches as shall be required; provided that no turnout shall be more than 150 ft. in length; nor within 500 ft. of any other turnout on the same street; nor within 150 ft. of any street corner; nor in M. and C. Streets, between the northerly line of said M. Street and the corner of R. Street; and provided also, that every turnout shall be laid equally on each side of said middle line of the street; and that such tracks shall be of the same gauge as that of the X. Y. Z. & N. Horse Car Railroad Co.

II. The rails to be used for said railroad shall be of steel, and of the kind or pattern now in use by the X. Y. Z. & N. Horse Car Railroad Co., within the limits of the City of X. Y. Z., and the sleepers, ties, chairs and spikes shall severally be of the best quality of their respective kinds; and both material and workmanship shall be subject to the inspection and approval of the Committee on Railroads of said Common Council; and said railroad shall not be operated for the transportation of passengers, and fares be collected therefrom, until so approved and accepted by said Committee, or a majority of them, in writing.

III. The spaces between the rails of the tracks, switches and turnouts, and between the tracks of the turnouts, shall be paved with cobble stone of medium size and of good quality, and to the satisfaction of both the Street Committee and the Committee on Railroads of said Common Council, or a majority of each of them, before the said railroad shall be operated for the transportation of passengers, and fares be collected thereon ; provided, that the best quality of Belgian blocks shall be used instead of cobble stones on D. and C. Streets, between the lines of W. Street and the M. & E. Railroad ; and provided also, that the cobble stones shall be removed and Belgian blocks of good quality be substituted therefor along the whole remaining line of said track, and switches and turnouts within four years next after said railroad shall go into operation as aforesaid ; such change to be made to the satisfaction of the said two committees or a majority of each of them ; and provided also, that all macadam or broken stone excavated or displaced in the streets as aforesaid shall be the property of the city.

IV. The said space between the rails and between the tracks, and a space of the width of eighteen inches on each side of the tracks on unpaved streets, shall be, at all times, kept and maintained in good order and repair by and at the expense of said company, and to the satisfaction of the Street Commissioner and Street Committee ; or, if not so kept and maintained, the repairs thereto may be made by or under the direction of said Committee, and to their satisfaction, and the expense thereof shall be paid, on demand, by said company to said city ; provided, the said Street Committee, or a majority of them, shall give at least ten days' notice, in writing, of their intention to make such repairs, the said notice to be served upon any officer or employe of said company who may be found at their office or stables.

V. The company, shall, in laying its tracks, switches and turnouts conform, in all cases, to the grade lines of the streets, as now established, or as they may hereafter be changed or established by the Common Council ; and said company shall, in case of any such change of grade, conform thereto, and alter such tracks, switches and turnouts at their own expense, and without unnecessary delay and under the direction of said Street Committee, or, in case of default, the said Street Committee shall make such a change, or cause the same to be made, and the expenses thereof shall be paid, on demand, by said company to said city ; provided, ten days' notice of the Committee's intention to make such change shall be given and served in the same manner as in case of repairs as aforesaid.

VI. In passing over the gutters of any cross street where the bottom of such gutters is or may be below the grade line of such railroad, the rails shall be securely laid and fastened upon iron bridges of the most approved pattern ; and such bridges shall be extended on each side of the track or tracks to the gutter line of the street in which said track or tracks is or are laid ; the bridges and work to be subject to the inspection and approval of said Committee on Railroads, in every particular.

VII. During the construction of said railroad no unnecessary hindrance or obstruction to ordinary travel upon any such street or streets shall be permitted ; and if any accident or other casualty shall happen or occur at any time, to any person or property, because or by reason of any work connected with such construction of said railroad, or afterwards because or by reason of any operation thereof, or through the carelessness or negligence of any of the company's officers or servants, agents or employes, the said company shall be liable therefor, and shall idemnify and save said city harmless from all cost, loss or damage by reason thereof.

VIII. The carriages to be used on said railroad shall be drawn or propelled by horses or mules, and not otherwise ; and no such carriage shall be drawn or propelled thereon at higher speed than at the rate of eight miles per hour : and it shall be the duty of the conductors and drivers, and each of them, to have bells hung upon such horses or mules, and to give other timely notice of the approach of such carriages to pedestrians and the drivers of other vehicles ; and for a violation of either of the provisions in this sub-section contained, the said company shall pay to the said city the penalty of twenty dollars for each and every offense, besides being liable for any damage or injury occasioned thereby ; and such carriages shall be constructed with a commodious platform or platforms that will provide ample room for the passengers getting on or off the same, and of a pattern to be approved by the Committee on Railroads.

IX. No carriage belonging to said company shall be allowed to stand in or obstruct any cross street. or stand upon any cross walk for any purpose whatever, or to stand or remain in one position upon any street for more than five minutes at any one time, except when said carriages shall be unavoidably obstructed or detained without the fault and negligence of said company, or any of its officers, servants, agents or employes, under the penalty of five dollars, to be paid by said company to said city for each and every offence.

X. The rate of fare for the transportation of any single passenger over the age of twelve years, upon any railroad, shall not exceed five cents for any distance in any one trip between the termini of the road.

XI. The said company shall, within thirty days next after the said railroad shall be put in operation as aforesaid, pay, or cause to be paid, unto the collector of taxes for said city, for the use of said city, a license fee for each and every carriage then running upon said railroad for the transportation of passengers as aforesaid; and a license fee for each and every carriage to be afterwards placed upon the said railroad for the purpose aforesaid shall be paid as aforesaid, within thirty days

next thereafter ; and all such licenses shall expire and be renewed for the term of one year, on the first day of every month of January thereafter ; and such license fees shall be at the rate of five dollars per annum for each and every carriage for the first five years that said railroad shall be operated, and subsequently, at the rate ot twenty dollars per annum for each and every carriage for every year thereafter ; and no such carriage shall be allowed to be used upon said railroad for more than thirty days as aforesaid, without having a proper certificate of license, duly signed by the Mayor and said collector of taxes of said city, conspicuously displayed therein, under a penalty of twenty dollars, to be paid by said company to said city for each and every offense.

XII. The said company and its officers, servants, agents or employes shall not, nor shall any or either of them, be allowed to shovel, throw or place any snow, ice or slush, alongside the said track or tracks, in any street or streets, in such manner as to obstruct other public travel therein ; but, when removing the snow, ice or slush from said track or tracks, the said company, or its said officers, servants, agents or employes, shall cause the same to be immediately levelled between the said track or tracks and the gutter lines of each side thereof ; under the penalty of twenty dollars to be paid by said company, or by any of its said officers, servants, agents or employes so offending, to said city for each and every offense.

XIII. The said city reserves the right to dig or excavate in or open any such street in which said railroad shall be so constructed, for the purpose of laying, examining, repairing or replacing any water or sewer pipe or pipes, or making or shutting off any connection therewith, or for the purpose of making any other public improvement, or of doing any other public work, of any kind whatsoever ; and the said company shall not have any recourse against said city therefor, for damages or otherwise, because of any detention or obstruction to the travel upon said railroad arising therefrom.

XIV. If the said company shall fail to build or construct the whole of said railroad, with its said turnouts and switches, in manner aforesaid, and to put the same in full and complete operation for the transportation of passengers, within one year next after the passage of this ordinance, or shall afterwards fail or neglect to operate the same as aforesaid, daily and every day, for the space of three consecutive months, all the rights, powers and privileges, and every of them, of said company, their successors or assigns, under and by virtue of this ordinance, shall thereupon cease and determine, and this ordinance shall become null and void, so far as the grant of any such right, power or privilege to said company is concerned ; and, in either of such cases, the Common Council expressly reserves the right to cause the said railroad, or any part or parts thereof, so constructed, to be removed from said street or streets, or any of them, and to sell and dispose of the materials thereof, by public auction, and, after paying all the expenses of such removal and sale and of repairing the street or streets, and of restoring the same as nearly as possible to its or their original condition, to pay the balance of the proceeds of such sale to the said company, or its successors or assigns, provided, that no notice of such sale shall be required to be given, other than an advertisement, signed by the city clerk, and published in one or more newspapers printed and published in said city.

XV. The said company shall file with the city clerk, within ninety days next after the passage of this ordinance, its acceptance, under its corporate seal, and signed by its president, of the terms and provisions, restrictions and regulations hereof, and every of them, and, in default thereof, it shall be understood and held that it declines to accept the same, and thereupon, all rights, powers and privileges, to it granted hereby, shall forever cease and be at an end, in the same manner and with the same effect as if this ordinance had never been passed.

Approved August , 188 .

Franchises may be perpetual or be granted for a limited number of years, and should contain provision for renewal or extension. In some cases the city agrees to purchase the plant at the expiration of the franchise. In one case where the franchise runs for twenty years, the agreement is that at the expiration of that time the city has the right only to purchase the railway at a valuation fixed by arbitrators. If not purchased at the end of the first twenty years the agreement runs on for five years longer, the city having the same privilege at the end of every fifth year.

A charter may be perpetual while the franchise is limited.

In reference to taxes and charges collected by the *state* other than those already mentioned, most lines are subject to a tax upon all real estate, the assessed valuation being a certain proportion to the actual value, according to local custom. Some are required to pay a tax on capital stock, without reference to dividends, while in other cases this tax is made contingent on dividends paid. The taxable value of capital stock is determined in various ways; the average value for which it is sold during the previous year, or by appraisement by the president and treasurer.

City taxes are usually assessed against railroad companies on real estate, the tracks being some-

times included at a certain valuation per mile, from $2,000 to $5,000, based upon the character and cost of construction. Sometimes a city imposes taxes on earnings in lieu of all other taxes, also on capital stock and on dividends. There are also water rates for stables—usually, so much per horse—and also, in some cases, a school tax.

As to paving and care of tracks there is a wide range of practice. In many cities no requirements are imposed, while others require the street to be paved between and outside the tracks for a short distance, as before noted, while a few require the railroad company to pave and keep the entire street in repair, and to lay flagging at the cross walks (a manifest injustice). The kind of pavement is sometimes specified, but not always. In a few instances the city provides the material and the company lays it and keeps it in repair, while others furnish all the material and do the work, but charge the railway company with the cost of all paving, repairs between tracks and two feet outside.

It is usually required that the pavement between the tracks be kept clean from dirt and snow, while in a few instances, in the far North, the companies are forbidden to remove the snow even from the tracks, but are required to provide sleighs for the transportation of passengers. In some cities the companies are required to sprinkle the pavement in summer time. Usually, it is required that the floors of bridges belonging to the city be kept in repair by the companies crossing them.

A license is frequently imposed by city ordinance at a fixed amount on each car per annum, in addition to the above taxes, the amount ranging from five to fifty dollars. Sometimes, the same amount is required on double and single cars, but, usually, the license fee for single cars is only one-half or two-thirds that for double cars. The license is sometimes imposed upon all the cars belonging to a company, whether box or open, and every other vehicle, no car being allowed to run without a license attached. In other cases the number is ascertained by the number of full days' work of conductors and drivers, or by counting a certain number of round trips as a day's work and 365 days to the year. The number running at any one time, in some cases, is the basis of estimate, and the license may be transferred from box to open cars, and *vice versa*. The average number running per day for 365 days, in some cases, forms the basis of estimate, while in others a certain number is designated and extras or extra time not counted, and no deduction is made when the number is reduced, on account of snow or other causes. The largest number of cars in use on any one day is also taken as a basis.

Manifestly, the most equitable basis for estimating the license fee would be on the mileage, counting on a certain number of round trips for a day. It is unfair to require a license for extra cars that may be run only once or twice in the year.

Other restrictions that are sometimes imposed, both by state and city authorities, relate to sanding or salting the tracks. Sanding is usually allowed, while some cities, under a grossly mistaken idea that salting the tracks for the purpose of melting the snow is injurious to the health of men and animals, prohibit it under various penalties, in one instance as high as $500 for each offense.

The above restrictions are cited, not with a view of recommending their adoption by city authorities in the granting of franchises, but rather to indicate the injustice that is frequently done to street railway corporations, and to advise that as few of them as possible be imposed upon companies seeking to operate a line of street cars.

Hundreds of cases may be cited to show that the street car service of a city is more or less satisfactory to the public, with liability to friction between the contracting parties, in proportion as the policy adopted by the local authorities in dealing with the street railway companies is a liberal or a restricted one.

It is a commendable practice for a street railway company to have printed in convenient form for reference, the general railroad law of the state, if there is one, or the various acts of the general assembly relating to railway corporations, together with a copy of the articles of incorporation or charter and copy of city ordinances relating to

the company, together with the by-laws of the company.

STOCKS

Is a term applied to the shares in the capital of railroads or other joint stock corporations, the par value of each share being fixed by the articles of incorporation, and may be for $10, $50, $100 or any other amount. The shares are usually represented by certificates, which may be printed in more or less elaborate form, and bear upon their face the number of shares which they represent. Shares are transferable upon assignment, and as they are constantly changing hands a record of transfer is usually kept upon the books of the corporation, in order that the actual stockholders may at any time be shown. All stock should be registered with a duly designated trust company as an additional guarantee to the integrity of the stock, and as a safeguard against a possible fraudulent over issue. The following is the usual form of a stock certificate :

THE P. & O. STREET RAILWAY CO.

THIS CERTIFIES *that* RICHARD ROE *is entitled to Twenty Shares in the Capital Stock of the* P. & O STREET RAILWAY COMPANY, *transferable on the books of the Company by the holder in person or by Attorney on the surrender of this Certificate.*

IN WITNESS WHEREOF, *the said Company has caused this Certificate to be signed by its President and Secretary, in the City of New York, this 10th day of January, 1891.*

.....*President.*

.....*Secretary.*

Stocks are divided into two classes, dividend and interest stocks; the latter are usually termed bonds, and will be described presently under that head.

Dividend stocks, or stocks simply, are those which call for a dividend of the net earnings of the business, and are secured by the net resources and earning capacity of the business or enterprise which they represent. They fluctuate in value, usually according to the success and prospects of the business, so that the dividends which are declared upon the shares regulate, to a great degree, their market value. It will be seen, then, that the true basis of value in stocks, is the permanent prospects of the business which they represent, and its real net earnings.

The state laws which make it incumbent upon corporations to publish at certain periods sworn statements of their affairs are calculated to further the interests of the public who may wish to invest, by furnishing reliable information from which to estimate the true value of the stock.

Dividend stocks are subdivided into two classes, common and preferred.

Preferred stock is created by special legislative enactment and may differ in any state. Holders of preferred stock are entitled, usually, to a certain fixed amount or per cent. of the dividends out of the net profit before, or in preference to, holders of common stock.

BONDS

Or interest stocks are those calling for a fixed rate of interest on the amount which they represent and are secured by mortgage on the property and franchise of the corporation. The value of bonds does not depend upon the percentage of dividends, but upon the character of the securities upon which they rest, and the market value of money. In case the authorized capital stock of a corporation has all been paid in and more money is required for improvements or for conducting the business, by vote of a certain number of the stockholders—usually two-thirds of the number of shares—money may be borrowed and bonds issued as security.

The manner in which this is usually done is as follows: The officers of the company execute a mortgage on the property and franchise of the corporation to a reputable trust company which in turn guarantees the payment of the bonds. The bonds are printed for a certain amount, and have coupons attached, stating the amount of interest payable annually or semi-annually. The coupons are cut off in order, as the interest installments are paid, and are equal in number to the interest periods before the bond becomes due. The following

is a copy of an ordinary bond which will give a definite idea of their character:

{No. 4.} [COPY OF BOND.] {$500.}

UNITED STATES OF AMERICA.

STATE OF M. N.

The X. Y. Z. Cross Town & Broomfield Railway Co.

20-*Year* 6 *Per Cent. First Mortgage Gold Bonds.*

[WHOLE ISSUE, $20,000.]

The X, Y. Z. Cross Town & Broomfield Street Railway Co. for value received, acknowledges itself to be indebted unto, and promises to pay to the holder of this bond on the first day of September, 1908, at the offices of the Central Trust Company, in the City of New York, FIVE HUNDRED DOLLARS in the United States Gold Coin, and also to pay interest thereon at the rate of six per cent. per annum, payable semi-annually at the Central Trust Company, as before said, in like gold coin, on the first days of September and March in each year, after the surrender of the proper annexed coupons as they severally become due as provided therein, and in case of default in the payment of any of the interest coupons attached to this bond in the manner provided in the said trust deed or mortgage, then, and in that case, the principal sum of the bond shall become due in the manner and with the effect provided in the said trust deed or mortgage. This bond is one of a series of forty bonds numbered consecutively from one to forty, inclusive, of like date, tenor, amount and effect, and payment of them all equally is secured by a deed of trust or mortgage bearing date September 1, 1886, duly executed by said Company, conveying to the Central Trust Company, of New York, trustee, the railroad and line of the Company located or to be hereafter located by said Company in the city of X. Y. Z. and the township of West X. Y. Z., in the county of E., State of M. N., and all other the property, rights, privileges, moneys, assets and franchises of said company, acquired or to be hereafter acquired and more particularly therein. Such trust deed or mortgage is a first lien upon all the property, rights and estates therein described. This bond shall not bind the Company until the certificate hereon endorsed is signed by the before mentioned trustee.

IN TESTIMONY WHEREOF, the said company has caused its corporate seal to be hereto affixed and these presents to be signed by its President, Secretary and Treasurer at the city of X. Y. Z. on the first day of September, 1886.

HENRY MARTIN, President.
ALEX. HILLHOUSE, Secretary.
WM. JONES, Treasurer.

INTEREST COUPON.

THE X. Y. Z. CROSSTOWN & BROOMFIELD RAILWAY COMPANY will pay to bearer on the first day of March, 1889, Fifteen Dollars in gold coin at the office of the Central Trust Company, in the City of New York, being six months' interest due that day on its Bond No. .....

WM. JONES, Treasurer.

The following is endorsed on the back of the above bond:

The X. Y. Z. Crosstown & Broomfield Railway Co.

FIRST MORTGAGE, SIX PER CENT., $500 GOLD BOND.

Interest Payable March 1st and September 1st.

Principal due September 1st, 1908.

Trustees' Certificate.—It is hereby certified that the X. Y. Z. CROSSTOWN & BROOMFIELD RAILWAY COMPANY has executed to us a mortgage or deed of trust, as described in the within bond, and that no more of such bonds have been certified by us than are authorized by said mortgage or deed of trust.

CENTRAL TRUST COMPANY, Trustee,
By ISAAC WALTON, President.

The directors of a corporation are usually restrained by law from disposing of the shares of capital stock for less than their par value, but the bonds may be sold for any price or given away.

The annual or semi-annual income to the holders of bonds is a fixed and certain amount (interest), without regard to the success of the business, while the income to stockholders is uncertain, depending upon the paying or passing of a dividend.

CHAPTER XII.

BOOKKEEPING AND THE CLASSIFICATION OF STREET RAILWAY ACCOUNTS.

Whatever benefits may accrue to a community from the existence of a street railway, the prime motive with the projectors and operators is *revenue*, and every means that tends to increase the net income should be carefully considered. No department of the service is more important or more responsible for securing this desired end than the accounting department. Any neglect in properly organizing or conducting this department will be as fatal to the financial success of a street railway company as would neglect in the operating department. Aside from matters relating strictly to the accounting for everything received, the accounting department incidentally gains considerable statistical information relating to the exact nature and extent of the numerous labors performed and the precise cost of movements, which furnishes the best obtainable data from which to rate the degree of skill and economy exercised in each department, and by each class of officials and employes. In order to properly conduct it, an efficient clerical force is necessary, and the work should be done in accordance with proper rules and regulations, and the items should be combined and condensed as much as possible. In order to assist in this direction the following analysis of accounts is presented, (see next page), which is based on the requirements of the Railroad Commissioners of the State of New York, under which all the street railway companies of the state are required to make annual reports to the Board. The requirements of other states may vary, but the same basis of division under different heads, and the same system of keeping accounts can be used, whatever the local requirement or personal fancy may be.

The following notes may be added in explanation of the analysis. They indicate the individual accounts that should be carried to the various headings.

3. COST OF ROAD AND EQUIPMENT.

1. SUPERINTENDENCE AND GENERAL EXPENSES.—To include salaries and personal expenses of general officers and superintendents, with their respective assistants and clerks, furniture, stationery, fuel and other office supplies.

2. ENGINEERING.—To include wages of engineers, draughtsmen and assistants, with office and other expenses.

3. RIGHT OF WAY.—To include cost of obtaining franchise, salaries and expenses of agents in securing consents, with all payments for right of way.

4. REAL ESTATE AND BUILDINGS.—To include cost of all real estate and buildings used exclusively for railroad purposes, together with all necessary furniture and fixtures.

NOTE :—*All real estate not so used should be charged, as an investment, to an account kept for that purpose.*

5. ROAD BED AND TRACK.—To include the cost of preparing the foundation, cost of all material and labor of distributing and laying same, including paving and wiring.

6. OVERHEAD CONSTRUCTION.—To include cost of poles, wire and insulating devices with expense of placing same.

7. ROLLING STOCK.—To include the cost of cars and trucks built or purchased, cost of grips, motors, wiring, trolley, switches, furnishings, etc.

8. AUXILIARY APPLIANCES.—To include cost of snow plows and sweepers, with electrical equipment or grips for same, wagons and other vehicles.

ANALYSIS OF ACCOUNTS.

1. History.
2. Capital Stock and Funded Debt.
3. Cost of Road and Equipment.
   1. Superintendence and general expenses.
   2. Engineering.
   3. Right of way.
   4. Real estate and build'gs.
   5. Roadbed and track.
   6. Overhead construction.
   7. Rolling stock.
   8. Auxiliary appliances.
   9. Power plant.
   10. Cable and carrying sheaves.
   11. Repair shops.
   12. Additions and betterments.
4. Income.
   1. Earnings
      1. Passengers.
      2. Express and mail.
      3. Advertising.
   2. Other sources
      1. Sale of manure, old material, and disabled animals.
      2. Interest and rents.
      3. Surplus of previous year.
5. Operating Expenses.
   1. Miscellaneous
      1. Salaries of general officers and clerks.
      2. Office service and supplies.
      3. Insurance.
      4. Legal
      5. Injury to persons and property.
      6. Contingent.
      7. Franchise account.
   2. Transportation
      1. Car service.
      2. Car barn.
      3. Lubricants and waste
         1. For cars.
         2. For power house.
      4. Supplies.
      5. Wrecking, sanding, sweeping and cleaning of conduits.
      6. Stable and power house.
      7. Provender and fuel.
   3. Maintenance of way and structures.
      1. Repairs and renewals of r'dbed and track.
      2. Repairs and renewals of overhead wire.
      3. Repairs and renewals of buildings, docks and wharves.
   4. Maintenance of rolling stock and power equipment.
      1. Repairs and renewals of cars and vehicles.
      2. Repairs and renewals of cable sheaves and grip dies.
      3. Repairs of harness and stable equipment.
      4. Horse shoeing.
      5. Renewals of horses and mules.
      6. Repairs of electric car equipment
         1. Motor armature.
         2. Gears and pinions.
         3. Trolleys.
         4. Miscellaneous.
      7. Repairs of power plant
         1. Steam.
         2. Cable.
         3. Electric.
      8. Tools and machinery.
      9. Miscellaneous.
6. Fixed Charges.
   1. Interest.
   2. Rent.
   3. Taxes.
   4. Franchise charges.
7. Balance Sheet.
   1. Assets
      1. Cost of road.
      2. Cost of equipment.
      3. Real estate and buildings.
      4. Stocks and bonds.
      5. Franchise.
      6. Other permanent investments.
      7. Cash on hand.
      8. Bills receivable.
      9. Open accounts.
      10. Supplies.
      11. Sinking fund.
      12. Sundries.
      13. Profit and loss (surplus).
   2. Liabilities
      1. Capital stock.
      2. Funded debt.
      3. Interest due and accrued.
      4. Dividends unpaid.
      5. Audited vouchers.
      6. Pay rolls.
      7. Open accounts.
      8. Bills payable.
      9. Sundries.
      10. Profit and loss (deficit).
      11. Deficit of previous years.

9. POWER PLANT.—To include cost of engines, boilers, cable winding drums, pit machinery, tension devices, generators, switchboards, shafting, belting, cranes, foundations, pumps, piping and labor of securing all in position, with heating and lighting appliances.

10. CABLE AND CARRYING SHEAVES.—To include cost of wire ropes, with carrying and terminal sheaves and placing the same ready for operation.

11. REPAIR SHOPS.—To include cost of iron working and wood working machinery, tools and power, if it is independent of the power plant, and the expenses of setting the machinery and appliances.

12. ADDITIONS AND BETTERMENTS.—To include such expenditures as actually increase the construction or equipment, and such expenses for renewals or repairs as exceed what is necessary to make good any depreciation of road and equipment.

4. INCOME.

1. EARNINGS.

a. From Passengers.—To include cash receipts for fare and sale of tickets.

b. From Express and Mail.—To include returns for transporting freight—express or mail.

c. From Advertising.—To include receipts for advertising in cars, buildings or on tickets.

2. OTHER SOURCES.

a. Sale of Manure, Old Material and Disabled Animals.—To include receipts from the sale of worn out animals, old materials and manure.

NOTE. *Receipts from these sources may be credited, if preferred, under "Operating Expenses" to the account to which the new material purchased to replace the old is charged. If the old material is not sold or replaced it may be debited to the "Supply" account and when used again or sold this account should receive credit for the same.*

b. Interest and Rents.—To include receipts for interest on securities or loans and receipts for buildings, grounds, leased lines or tracks, and power leased to other parties.

c. Surplus of Previous Years.—To include the net income, less the payments made therefrom on the business of the previous year.

5. OPERATING EXPENSES.

1. MISCELLANEOUS.

1. SALARIES OF GENERAL OFFICERS AND CLERKS.—To include salaries of general officers, heads of departments, division superintendents and wages of their respective assistants and clerks.

2. OFFICE SERVICE AND SUPPLIES.—To include the expense of heating and lighting the general offices, wages of porters, messengers, advertising, printing of blanks, tickets and circulars, stationery, blank books, tools, etc.

3. INSURANCE.—To include cost of insurance on any property used for railroad purposes, cost of guarantee against accidental bodily injuries or death of employes, passengers and the public, cost of conducting employes' mutual aid association, including expense of collections.

NOTE. *Insurance on property other than that used for railroad purposes should be charged against the property insured. The cost of guarantee may be charged to "Injuries to Persons and Property," if preferred.*

4. LEGAL.—To include salaries, fees and expenses of attorneys and all legal expenses of every kind.

NOTE. *A portion of legal expenses may be divided up between "Injuries to Persons and Property," "Real Estate" or "Franchise" as the services are rendered.*

5. INJURIES TO PERSONS AND PROPERTY.—To include payments made for damages to or destruction of property (not belonging to the company), for persons killed or injured, wages of the employes while disabled, medical attendance or any other expenses (except legal) incident thereto.

6. REMOVAL OF SNOW AND ICE.—To include cost of labor, salt and other expense incident thereto.

7. CONTINGENT.—To include any miscellaneous expenses or rents incurred exclusively in the operation of the road for which other provision is not made.

8. FRANCHISE ACCOUNT.—To include cost of repaving streets, over and above the repairs to pavements, which are chargeable to maintenance of way.

2. TRANSPORTATION.

1 CAR SERVICE.—To include the wages of all men employed on or about the cars while in ser-

vice, chief conductor, inspectors, starters, with their respective aids.

2. Car Barn.—To include wages of barn foremen and all persons employed for shifting, cleaning or inspecting cars, tools for same, cost of heating and lighting barns and sheds.

3. Lubricants and Waste.— To include oil, grease, tallow and other lubricants, and waste employed on the journals of cars and motors, and on the engines, shafting, winding drums, generators and pumps in the power house, and on the rope and carrying pulleys.

4. Supplies.—To include such supplies as are not charged to repairs, such as conductors' punches and portable registers, flags, lanterns, switch sticks, etc.

5. Wrecking, Sanding, Sweeping and Cleaning Conduit.—To include the cost of replacing derailed cars and removing obstructions and wrecks, with the wages of men employed especially for this service, and cost of tools. Cost of sweeping track, cleaning conduit, sanding track from car or by special means.

6. Stable and Power House.—To include the wages of foreman, engineer, electrician and all employed in and about the stable or power house.

7. Provender and Fuel.—To include the cost of feed and the labor of grinding, cutting and preparing for use, and cost of bedding, medicine and veterinary services. Cost of fuel employed in the power house, with freight charges on the same, water rates and cost of pumping.

3. maintenance of way and structures.

1. Repairs and Renewals of Road Bed and Track.—To include cost of all material and tools (rails, ties, paving blocks, sand, etc.), with the cost of labor, (wages of roadmaster, foreman and laborers) in maintaining, repairing and placing new material for track, joints, switches, bonds and supplementary wire, and tracks in buildings.

2. Repairs and Renewals of Overhead Construction.—To include cost of repairs and renewals of poles, all wires and all suspension and insulating appliances.

3. Repairs and Renewals of Buildings, Docks and Wharves.—To include cost of all material and expense of distributing same, and all labor performed in repairs of offices, stables, stations, buildings, scales, car and repair shops, power house and any other buildings, turntables, cranes, pits and wharves.

Note. *Repairs to buildings or other property not used for railroad purposes are to be charged against the property.*

4. maintenance of rolling stock and power equipment.

1. Repairs and Renewals of Cars, Sweepers, Snow Plows and other Vehicles.—To include cost of material and labor in repairing, renewing or rebuilding cars and appurtenances belonging thereto, such as trucks, grips, brakes, journal boxes, springs, scrapers, pilots, sand boxes, signs, wheels and axles. Cost of new cars purchased to make good any depreciation.

2. Repairs and Renewals of Cables, Grips, Dies and Sheaves.—To include cost of ropes, splicing and placing the same in line; cost of lining and renewing carrying pulleys and terminal sheaves.

3. Repairs of Harnesses and Stable Equipment.—To include cost of material and labor in repairing or renewing, or of new harness or stable equipment purchased to make good any depreciation.

4. Horse Shoeing.—To include cost of material and labor and cost of adjustable shoes.

5. Renewals of Horses and Mules.—To include cost of horses and mules purchased to replace those worn out.

6. repairs of electric car equipment.

a. Motor Armatures and Fields.—To include the cost of new material and the labor of removing, repairing, replacing and making all connections for these parts, and the cost of new armatures and fields purchased to make good any depreciation.

b. Gears and Pinions.—To include the cost of repairs and renewals, with the labor of removing and replacing, and the cost of new gears and pinions to take the place of those discarded.

c. Trolleys.—To include the cost of repairs, renewals, labor, and new trolley poles and wheels to replace those damaged or destroyed.

d. Miscellaneous.—To include repairs of motors and fields other than those above noted, and repairs and renewals of all auxiliary electric appliances, such as switches, lightning arresters, rheostats, pans, brush holders, brushes and fuses.

NOTE.—*If preferred, the cost of brushes and fuses may be charged to supplies under the transportation expenses, as, strictly speaking, they are not repairs.*

7. REPAIRS OF POWER PLANT.

a. Steam Plant.—To include cost of repairs of engines, boilers, pumps, steam pipe, belts and shafting.

b. Cable Plant.—To include cost of renewals and repairs to winding drums, gears and tension apparatus.

c. Electric.—To include cost of renewals and repairs to generators and their parts, with the labor of removing and replacing; also renewals of switch-board equipment and all connections.

8. TOOLS AND MACHINERY.—To include cost of repairs and renewals of repair and car shop equipment.

9.—MISCELLANEOUS.—To include all expenses of maintenance of equipment not provided for as above.

6. FIXED CHARGES.

1. INTEREST.—To include all payments made on account of funded or floating debts.

2. RENTS.—To include rentals of leased lines and buildings, stables, power houses, sheds and buildings for railroad purposes.

3. TAXES.—To include such as are assessed on property used in the operation of the road, on earnings, capital stock, and other than the foregoing.

4. FRANCHISE CHARGES.—To include any payments made to the city on gross earnings, in a consideration of franchise.

BOOKS.

Having properly analyzed the accounts, the bookkeeping becomes a comparatively simple matter. Two principal books only are required; the number of auxiliary books, or report blanks, will depend upon the extent and number of departments into which the business is divided. The principal books are known as Journal or Distribution Book and Ledger.

The JOURNAL OR DISTRIBUTION BOOK may be kept in different ways. One form of ruling is shown in Form B, headed "Operating Expenses." This method requires that the pages of the Journal be about 28 × 17 ins., which is bound with a number of divisions to correspond with the number of ledger headings required. Each division is ruled to suit the number of sub-headings required, and a tag is inserted to mark the beginning of the divisions. By this method the sum total is carried to the debit of an account under "Operating Expenses" in the ledger, so that the various charges under the several headings do not take up the room on the ledger, but are condensed under the one heading, the details appearing only in this distribution book. The following embrace all the ledger headings that are employed in a set of books that represent the business of a very large system of animal traction:

Capital Stock,	Equipment,
Bonds,	Real Estate & Buildings,
Treasurer,	Operating Expenses,
Profit & Loss,	Interest,
Passenger Earnings,	Taxes,
Miscellaneous Earnings,	Accounts Payable,
Supplies,	Accounts Receivable.
Construction,	

The same thing is done with the "Equipment Account." A division of the distribution book has a heading and under it the various columns show cost of cars, horses, motors, etc., and at the end of each month the sum total is carried to the account called "Equipment" in the ledger.

The same for "Construction;" the columns showing amounts expended for rails, road bed, etc. By this means the details of all expenses, whether on account of capital, operation, interest, taxes, etc., are entered in the distribution book, and each month the sums total are carried to these various accounts in the ledger, the items of which can be found in detail by reference to the distribution book.

In keeping supplies, the purchases may be made and charged to the various operating accounts for

Form D.

Operating Expenses.

January 1892

Date	Check or Voucher No:			Repairs of Roadbed & Tracks	Repairs of Building Fixtures	Repairs of Cars and Vehicles	Repairs of Motors	Repairs of Harness	Horse Shoeing	Renewals of Horses	Cost of Provender	Mill Expenses	Salaries of Officers and Clerks	Wages of Conductors and Car Employees	Wages of Depot Employees	Fuel for Cars and Depots	Gas and Light	Fuel for Power Station	Depot and Stable Supplies	Printing & Office Expenses	Damages	Legal Expenses	Water Supply	Insurance	Removal of Snow & Ice	Rents	Contingencies	Interest	
1	28129	J. Brown Paymaster	Pay Roll Week ending Jan. 1		314.50	1244.86	232.39	114.38	947.00			98.00	686.92	1999748	896879		190.56				38.36				71.80				32905.04
	28130	Del. Car Wheel Co.	Wheels			537.50																						537.50
2	28131	John Doe	54 Horses							5090.00																		5090.00
	28132	Richard Doe	7193 Bushels Corn @ 40¢ & Elevating								2899.00																	2899.00
4	28133	James Peters	314 tons Broken Coal @ $4.45															1397.30										1397.30
5	28136	James Fox	302 tons Nut Coal @ $3.50													1057.00												1057.00
7	28138	W. J. McHugh	137.39 Tons Straw @ 80¢ p 100 251136 - Hay . 48¢ . .								1343.73																	1343.73
	28140	Geo. Seaman	Lumber	962.00																								962.00
	28141	Wm Van Buren	Sand	162.00																								162.00
8	28142	Wilson & Co.	Stable Brooms																27.69									27.69
	28143	Pure Water Co.	Water																			67.40						67.40
	28144	Evans & Co.	Insurance to Jan. 1893																				1764.00					1764.00
9	28145	Chas. Mathews	Castings &c.	412.00		54.00																						466.00
10	28146	W. J. Field	Stationery																	29.47								29.47
11	28147	J. C. Smith	Investigating patent infringement claim																		764.29							764.29
12	28148	John Jones	Traveling Expenses																							75.40		75.40
14	28149	James Carey	Salt																					460.00				460.00
15	28150	Thos. Graer	Rent for Waiting Room and Transfer Office																						50.00			50.00
	28151																								75.00			75.00
				1536.00	314.50	1836.36	232.39	114.38	947.00	5090.00	4242.73	98.00	686.92	1999748	896879	1057.00	190.56	1397.30	27.69	29.47	38.36	764.29	67.40	1764.00	531.80	125.00	75.40		$ 50132.82

which supplies are purchased; for instance, provender and the cost of preparing the same for use, under "Cost of Provender;" hardware, wheels, car equipment, etc., to "Repairs of Cars;" rails and other supplies for track to "Repairs of Track," etc. At the end of each month an inventory is taken of the supplies on hand and deducted from those various accounts, thereby showing the exact amount of expenditure for those repairs, cost of feed, etc., leaving the supply account debited with the amount of supplies actually on hand. By this means the company will always know what supplies are on hand and paid for and the various accounts will only be debited with the amounts actually used.

The receipts may be kept in the same book by having a department for "Passenger receipts," with the pages ruled so as to show the receipts from different divisions of the system, and another department for "Miscellaneous Receipts." In this case no cash book is required as the check stubs and petty cash book show all cash payments.

A Cash Book, of which Form A will serve as a model, may be used if preferred. This is headed on its opposite pages "Receipts" and "Disbursements." The "Receipts" side in the cash book shows the name of the conductor, the amount of cash for tickets, the amount of "cash fares," the "Total" of the two foregoing; the total for each line being carried into the column under its proper head; tickets sold in office are entered under "tickets" and carried to "office" column, any other receipts are entered under "Miscellaneous." The total line receipts each day are carried to the total column as are all other receipts. The "Disbursements" side shows the name and the check number and when an audited voucher is paid the number is entered under "A. V. No." and the amount entered under "Audited Vouchers," and the total audited vouchers for the day carried to the "Total" column. For other disbursements the check number is entered under "Check No." and the amount under "Sundries;" for instance, if it is pay roll, which is divided into ten different parts, each part is entered separately and the total carried to the "Total" column. Any other payment would be entered under "Miscellaneous," and the amount under that head carried to "Total"

(A) RECEIPTS. ..... 1892.

Name of Conductor.	L. F.	Tickets.	Fares.	Total.	Brown Street Line.	White Street Line.	Green Street Line.	Fifth Street Line.	Office.	Miscellaneous.	Total.	

DISBURSEMENTS. ..... 1892.

	L. F.	Check No.	A. V. No.	Sundries.	Audited Vouchers.	Miscellaneous.	Total.	Balance in Bank.	Cash on hand.

(C) TRANSPORTATION.

Date.	L. F.	A. V. No.			Sundries.	Audited Vouchers.	Supply Account.	Cash.	Car Service.	Transportation.

column each day. The two columns "Balance in Bank" and "Cash on Hand" are merely memoranda to show at a glance the two items.

At the end of the month posting may be done direct from the cash book to the ledger of the totals of the several lines, and the total of the "Office" column and the items under "Miscellaneous" to the several accounts to which they belong. The "Disbursements" side items are posted separately to the ledger, except the "Audited Vouchers" which can be posted in bulk.

A modification of the journal, shown in Form B, can be made to conform more nearly with the analysis given on page 360. In this case the divisions of the journal may be given the first subheading (General Expenses) under operating expenses, and the columns ruled to correspond with the final sub-divisions. This will necessitate a few more accounts in the ledger, or the items may be combined and posted under "Operating Expenses."

In order to reduce the size of the journal page, and for other reasons, Form C may be employed. With this method the journal is divided and classified to correspond with each ledger account; for instance, "General Expenses," "Transportation," "Maintenance of Way," "Structures," etc., and to each division is assigned a certain number of pages.

The name of the division "Transportation" is printed on the top of each page of that division, and on the margin of the first page of each division (see Form C), and the preceding leaves are cut out after the manner of an index, and at the beginning of each division a leather tag is placed, which extends beyond the leaves and on which the name of the division is printed, and serves as a ready reference to any division. The sub-head "Car Service" is printed, in the last column, and a sufficient number of pages are devoted to each of the subdivisions.

Each item chargeable to any account is entered in full, the audited voucher number, name of the firm, from whom the purchase was made, the article, so that all items charged to any account are readily referred to without consulting any other book, the audited voucher number being entered

(D) THE PEOPLE'S RAILWAY.

Statement of Operating Expenses for 189

General Expenses.			
Salaries of General Officers			
Salaries of Clerks in General Office			
Miscellaneous Expenses, General Office			
Stationery and Printing			
Insurance			
Legal Expenses			
Injuries and Damages			
Contingent Expenses			
Stable Expenses			
Transportation Expenses.			
Car Service			
Car House Expenses			
Oil and Waste for Cars			
Operation, Power House			
Coal, Power House			
Oil and Waste, Power House			
Light and Fuel, Cars			
Maintenance of Way and Buildings.			
Repairs of Roadway and Track			
Renewals of Rails			
Renewals of Ties			
Repairs and Renewals of Paving			
Repairs of Overhead and Sup. Wire			
Repairs of Buildings			
Maintenance of Equipment.			
Repairs of Cars			
Repairs of Electrical Equipment:			
(*a*) Armatures and Fields			
(*b*) Gears and Pinions			
(*c*) Trolleys			
(*d*) Sundry Repairs			
Repairs of Steam Plant			
Repairs of Electrical Plant:			
(*a*) Dynamos			
(*b*) Switchboard			
Tools and Machinery			
Miscellaneous Expenses			
Fixed Charges.			
Interest			
Rent			
Taxes			
Receipts for Month			
Expenses for Month			
Surplus			
Construction and Equipment.			
Building Construction			
Track and Roadway Construction			
Overhead Construction			
Car Equipment			
Snow Plows and Sweepers			
Power Station Equipment			
Tools and Machinery			
Improvements and Betterments			
Cash on hand			
Supplies			
Floating indebtedness			

so that the original bill may be referred to with very little trouble.

The three columns headed "Sundries," "Audited Voucher" and "Supply Account," represent the principal credit accounts, and at the end of each month the totals of each account are posted to the debit side of the ledger and the grand totals of the three columns for the month are posted to the credit side of the ledger account represented.

The auxiliary books or blanks may be ruled to suit the different accounts for which they are to be used; for instance, the record of armature repairs is made from the armature repair tag, which is sent to the office from the repair shop, and which is illustrated with other blank forms in this connection. The following are the points to be noted: 1. Armature No. —, 2. Extent of Damage, 3. Date Damaged ——, 4. Cause of Damage, 5.

FORM E.

	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	For Year.
Miles between Termini	11.692	11.692	11.692	11.692	11 692	12.407	12.407	12.407	12.407	12.407	12 407	12.407	12.109
Miles of Single Track	23.384	23.384	23.384	23.384	23 384	24.814	24.814	24.814	24.814	24.814	24.814	24.814	24.218
Miles Run by Cables	31.926	28.881	31.989	31.089	33.670	33.466	35.029	34.938	34.202	35.325	33.793	35.214	399.542
Average Number of Trains Run	44 6	45.9	45.6	46.3	45.2	45.8	45.4	45	43.8	43.8	41.3	41.2	44.6
Total Number of Round Trips	22,531	20,706	22 644	22,291	23,006	21.612	22,993	22.533	21,021	21.451	19,300	19,910	259.998
Car Mileage	363,962	334,376	365,884	360,068	373,048	369,967	393.101	385,835	360,240	367,504	331,823	342,905	4,348,713
Passengers Carried for Revenue	826,003	718,801	794,653	927,339	959,810	979,723	1,039,362	1,024,325	1,023,523	1,126,949	830,566	871,967	11,128,021
EARNINGS.													
Car Fares	$41,300.15	$35,940.05	$39,732.65	$46,366.95	$47,990.50	$48,986.15	$51,968 10	$51,216.25	$51,426.15	$56,347.45	$41,528 30	$43,598.35	$ 556,401.05
Advertising	181.10	182.15	182.70	181 25	181.95	184.80	184.25	185.00	183.27	182.85	182.40	181.65	2,193.37
Rents	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	30.00	15.00	45.00
Miscellaneous	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total Earnings	$41,481.25	$36,122.20	$39,915.35	$46,548.20	$48,172.45	$49,170.95	$52,152.35	$51,401.25	$51,609 42	$56,530.30	$41,740.70	$43,795.00	$ 558,639.42
OPERATING EXPENSES.													
Car Service and Expense	$13,846.82	$12,831.95	$13,715.22	$13,209.43	$13,000.71	$12,836.00	$13,097.42	$11,903.08	$10,533 29	$11,063.05	$10,174.89	$10,735.45	$ 146,947.31
Injuries to Persons and Property	2,532.07	1,722.86	1,570.33	4,209.29	2,804.10	1,982.78	2,013.23	1,102.39	1,493.29	1,031.82	987.57	3,053.94	24,503.67
Car Licenses	274.97	285.41	285.41	308.33	304.17	304.17	306.25	308 32	293.80	308.42	277.92	281.65	3,536.82
Repairs of Cars	797.75	727.68	851.49	664.70	580.89	730.29	677.49	732.55	570.41	729.97	1,013.70	835.78	8,912.70
Repairs of Grips	435.72	421.10	541.04	567.44	552.59	511.14	387.79	479.19	445.29	418.23	460.99	512.19	5,732.71
Motive Power	10,890.97	11,566.46	10,640.03	9,080.57	10,032.50	11,023.82	11,224.05	10,552.25	10,991.21	12,143.95	12,155.20	12,174.85	132,475.86
Maintenance of Track and Build'gs	718.34	716.76	534.35	573.45	571.73	596.21	1,134.89	1,394.42	2,199.97	2,296.72	683.24	803.62	9,198.53
General and Miscellaneous	3,226.35	2,337.16	2,703.91	2,179.89	1,996.73	2,535.21	1,132.64	2,260.04	810.05	733.08	2,355.94	2,484 67	27,709.13
Advertising and Attractions	.....	36.40	406.90	76.88	129.59	289.87	349 54	325 11	513 00	67 54	.....	.....	3,160.42
Taxes	869.55	1.048.10	884.58	870.10	873.45	887.16	1,178.84	707.45	.....	.....	579.97	166.11	8,645.85
Total Operating Expenses	$33,592.54	$31,693.88	$32,133.26	$31,740.03	$30.846.46	$31.696.65	$31.502.04	$29,664.80	$28,685.43	$29,532.18	$28,689.42	$31.048.26	$ 370,825.00
Per Cent. of Earnings	80.98	87.74	80.50	68.19	64.03	64.46	60.40	57.71	55.58	52.24	68.73	70.89	66.38
Cost per Car per Mile	9.2c	9.5c	8.8c	8.8c	8.3c	8.6c	8c	7.7c	8c	8c	8.6c	9c	8.5c
Net Earnings, 1891	$ 7,888.71	$ 4 428.32	$ 7,782 09	$14,808.12	$17,325.99	$17.474.30	$20.65).31	$21,736.45	$22,923.99	$26.998.12	$13.051 28	$12,746.74	$ 187,814.42
Net Earnings 1890	$ 3,924.27	$ 6.428.11	$ 8,566.09	$15,764.01	$24,034.54	$23,274.26	$21,845.93	$20.997.26	$23,981.41	$22,212.06	$16,702.27	$14,641.19	$ 202,371.39
Increase	$ 3,964.44	.....	.....	.....	.....	.....	.....	$ 739.20	.....	$ 4,786.06	.....	.....	.....
Decrease	.....	$ 1,999 79	$ 784 00	$ 955.89	$ 6.708.55	$ 5,799.96	$ 1,195.82	.....	$ 1.057 42	.....	$ 3 650.99	$ 1,894.45	$ 14.556.97

Items that do not come under either printed head can be all carried into the sundries column and posted direct to the ledger.

The ledger is ruled in the usual form, and does not differ from those used in ordinary bookkeeping.

As an aid to forming the divisions and subdivisions of the journal, the accompanying Form D is presented, which is a monthly statement made from a journal kept in the manner last described, and, it will be seen, is composed of five departments with their subdivisions. The analyses of accounts given in this form do not correspond in all respects with that given on page 360, but are very satisfactory.

From Car No. —, 6. Motorman, 7. Repaired by ——, 8. Time Consumed, 9. Placed in Car No. —, 10. Date Same was Replaced.

Books for the daily and weekly horse report and power house reports with engineer's log book and others are also necessary.

Form E is offered as a desirable model from which a manager may make a summary of an annual report to his board of directors. The form is reproduced without altering the figures from the annual report of the manager of a large street railway system.

The following statistical forms are self-explanatory.

STATISTICS.

EARNINGS.	1891.	1892.
Gross Earnings from Passengers		
" " per Mile of Street		
" " " " Track		
" " " Car Mile		
" " " Capita served		
" " " Passenger Carried		
Other Income " Car Mile		
OPERATION.		
Car Miles Run		
Passengers Carried		
" " per Car Mile		
Population Served		
Area Served, Square Miles		
Operating Expenses:		
General Expenses per Car Mile		
Transportation " "		
Maintenance of Way " "		
" of Equipment per Car Mile		
Total Operating Expenses " "		
" " " " Passenger Carried		
Fixed Charges per Car Mile		
" " " Passenger Carried		
EQUIPMENT.		
Capital Stock per Mile Track		
Funded Debt " " "		
Other Debt " " "		
Cars in Service		
" " " per Mile Track		
Repairs Roadbed per Mile Road		
" Equipment " "		

ROAD AND EQUIPMENT.

Roadbed:		
Miles of Single Track		
" of Double "		
Total Mileage of Track		
" " of Street		
Miles of Cable Conduit		
Overhead Construction, Miles		
Power Station		
Horse Power Engines		
" " Dynamos		
Barns and Stables:		
Number of Horses		
Rolling Stock:		
Number of Closed Cars		
" " Open "		
" " Motors		
" " Grips		
" " Snow Sweepers, etc.		

CONSTRUCTION AND EQUIPMENT.

Roadbed:		
New Lines of Double Track		
" " " Single "		
" Second Track		
" Conduit Construction		
" Track Wiring		
Overhead Electric Construction		
Power Station:		
Additions to Steam Plant		
" " Electric "		
" " Cable "		
Barns and Stables:	1891.	1892.
Increase of Horses		
" " Equipment		
Rolling Stock:		
Additions to Closed Car Bodies		
" " Open " "		
" " Trucks		
" " Motors		
" " Grips		
Repair Shops:		
Additions to Plant		
Totals		

RECAPITULATION.

Gross Earnings		
Operating Expenses		
Earnings over Operating Expenses		
Fixed Charges		
Net Earnings		
Construction Account		
Surplus Applicable to Dividends		
Dividends Paid		
Surplus Account		

PERCENTAGES.

Percentage Operat'n Exp'n'es to Gross Earnings		
" Fixed Charges " " "		
" Net Earnings " " "		
" Dividends on Stock		
" Interest on Bonds		

RECORD BLANKS.

The following forms, which are copies of those used on a well managed line, will be found admirably adapted for the purposes specified.

RECORD OF EMPLOYES.

The blank (form F, note size) should be handed the applicant when he is engaged, and he should also be furnished with a copy of the Rule Book, and with a copy of instructions to motormen if he is to operate an electric car. When this form is returned and the report is favorable, form G should be furnished, which, after it has gone its rounds, should be returned to the superintendent's office, when the two forms should be attached together and filed away alphabetically in a case provided for the purpose. When an employe leaves the service he should be required to present to the secretary and treasurer, a note from the superintendent (form H) which, when it is returned, should be attached to the other slips relating to the case; thus a complete record will be kept of the dates when a party entered or left the service, and which will show where the party may be found after leaving the service.

ACCIDENT AND DAMAGE BLANKS.

A book of blanks (forms I and I[1]) should be provided for the conductors, one of which he should be required to fill out in case of an accident to persons or damage to property, the same forms being used in both cases; the two forms, however, may be printed on different colored paper. When filled it should be torn from the book and sent to the superintendent's office. On being received at the office it should be filed away for reference, and a copy, if necessary, should be sent to the claim agent of the company, who should interview the witnesses at once.

DAILY POWER HOUSE REPORT OR LOG BOOK.

The power house daily report is shown in form J. The foreman should be also required to make a report of supplies drawn each day.

A large sheet should also be provided (form K) on which should be printed the names of all electrical parts, classified, and small car parts, on which the storekeeper of the motor repair department should make his report to the superintendent.

WINDOW AND DOOR GLASS RECORD.

Form L is a blank 10 × 12 ins., which is designed not only for keeping a record of broken glass, but also to prevent breakage; for after the men are confronted a few times with this record they will learn to be more careful.

ARMATURE REPAIRS.

Form M is a copy of the front and reverse sides of the eyelet tag which should be provided, for use as per directions on the reverse side. At the office a book properly ruled should be kept, into which the contents of the card should be copied. By this means the cause of damage will be recorded, and an accurate account will be kept of all armatures repaired, and by whom made.

(F)

APPLICATION BLANKS.

X. Y. Z. RAILWAY COMPANY.

BROWNSTOWN, *February 6th,* 1892.

Mr. *Samuel Jones,*

Foreman *First* Ave. Division.

Place bearer Mr. *Paul Geary,* on with

Peter James, John Smith, and Henry Robinson,

for instructions in the duties of *Conductor.*

B. G. Smith, Sup't.

To Sup't X. Y. Z. Railway Company:

Bearer *Paul Geary,*

has been under instructions with the undersigned for the number of days set opposite our names.

He is familiar with all rules and regulations, and with the streets along this route.

He is also familiar with all switches, curves and turnouts about the station, and the various branches connecting with this division, and I recommend him.

On with	*Peter James*	2	days.
"	*John Smith*	3	"
"	*Henry Robinson*	2	"

(G)

BROWNSTOWN, *February 13th,* 1892.

I, *Paul Geary,*

Born in *Brownstown,*

Age 30 Married.

Residence 2900 *Hill Street,*

Desire employment with the X. Y. Z. Railway Company

as *Conductor,*

at *First* Avenue Division.

I have been furnished with a printed copy of the rules and regulations governing motormen and conductors of this company, have carefully read the same, and agree to cheerfully comply with all of said rules, regulations and conditions contained therein.

Occupation during last two years as follows:

Driver, Suburban & Eastern Railway Co., 8 months; Conductor, People's Railway Co., 16 months.

Respectfully,

[Signed.] *Paul Geary.*

Recommended by *Frank Brown of Sub. & E. Ry. Co., Thomas Smith of People's Railway Co.*

Deposit made and badge furnished.

Thomas Hall, Sec'y.

Mr. *Samuel Brown,* Foreman:

Please assign Mr. *Paul Geary* to a place on the "Extra" List.

B. G. Smith, Supt.

Reported for duty, *February 15th,* 1892.

Sam'l Brown, Foreman.

(H) X. Y. Z. RAILWAY COMPANY.

BROWNSTOWN, *Aug. 1st,* 1892.

JOHN JONES, Treasurer:

Please pay (between the hours of 2 and 3 o'clock P. M.)

Paul Geary

the amount due him to date.

B. G. Smith, Supt.

Resigned to go to Chicago, Ill. Address, 541 Dearborn St.

(I)

ACCIDENT REPORT BLANK.

Brownstown, January 1st, 1891.

On our 7:40 P. M. trip going East, at Broadway and Market Streets, a lady stepped off the car before the same was stopped. The bell was rung for the crossing, but she jumped off on the West side and fell. I stopped the car immediately and went back to her, but she was not hurt. Gave her name as Mrs. A. S. Goodmin, No. 3490 Belton Ave.

Witnesses: { *N. Robins, 708 N. John Street.*
G. J. Martin, 1240 Broadway.

W. Jones, Motorman Car No. 20.
A. Smith, Conductor " "

(I¹)

DAMAGE REPORT BLANK.

Brownstown, January 1st, 1891.

On our 8:10 A. M. trip going East, at Twelfth and Martin Streets, we collided with a wagon belonging to the Thompson Commission Co., of 1130 Jefferson Street, in charge of John Hopkinson, damaging the same slightly and bending the dash of our car, No. 84. The driver pulled directly in front of us, within ten feet of the car, not giving the motorman time to stop.

Witnesses: { *Jas. Wright, 102 N. Fourth Street.*
A. Peters, 4128 S. Broad Street.

A. Wilkinson, Motorman Car No. 86.
P. Herbert, Conductor " "

(J)

ENGINEER'S LOG BOOK.

December, 1891.

Generator No. 1. Time.			Generator No. 2. Time.			Generator No. 3. Time.			Voltage.	Averagé Amperes.	Average El. H. P.	Remarks.
On.	Off.	Run.	On.	Off.	Run.	On.	Off.	Run.				
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Engine No. 1. Time.			Engine No. 2. Time.			Engine No. 3. Time.			Steam Pressure.	Average Eng. H. P.	Pounds Coal Received.	Remarks.
On.	Off.	Run.	On.	Off.	Run.	On.	Off.	Run.				
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

(K)

STOREKEEPER'S REPORT BLANK.

Brownstown,..... 189

B. G. Smith, Sup't X. Y. Z. Railway Co.:

I herewith report the following material furnished from storeroom.....Avenue Division, this day and date.

Material.	Quantity.	Size.	Description.	For Car No.	For Car No.	For Car No.	For Car No.	For Car No.	For Car No.	For Car No.	For Car No.	To Whom Delivered.	Quantity Old Material Returned.
(1) Armatures:	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" Pinions	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" Pinion Keys	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
etc.													

(L)

GLASS RENEWAL SLIP.

Day..... Date 189

Car No.	Conductor.		Door Glass.	Side Windows.	End Windows.	Dome Glass.	Cause of Breakage.
	Name.	No.					

Remarks.—The foreman in charge must fill out car number and glass replaced, which information must be furnished him by the carpenter replacing same. This slip must then be posted in the conductors' waiting room not later than 5 o'clock A. M., and must be left there until 9 o'clock P. M. Conductors must fill out their name and number and cause of breakage.

ARMATURE TAG.

(Front—M)

1. Armature No. 6342

2. Extent of Damage *Bands on outside loose, also damaged commutator.*

3. Date Damaged *Feb. 5th, 1892.*

4. Cause of Damage *Worn out brasses.*

5. From Car No. 5

6. Motorman *H. Smith.*

7. Repaired by *Thomas Brown.*

8. Time Consumed 8 Hours.

9. Placed in Car No. 6

10. Date same was replaced *Feb. 10th, 1892*

(Reverse—M)

A tag must be attached to each Armature taken out, by the Foreman or some person designated by him, who must fill out the first six (6) lines.

The seventh and eighth lines must be filled out by Armature Winder repairing same, who must return the tag, securely attached, to the Armature.

The tag must be left on the Armature until the same has been placed in some car, when the Shop Foreman must fill out the last two lines and return the tag to the Superintendent's office.

B. G. Smith,
Superintendent.

(N)

MILEAGE SHEET.*

X. Y. Z. STREET RAILWAY COMPANY.

Daily account of trips run and Monthly Report of Revenue Mileage of { Single..... / Double..... } Motor Electric Car No..... and Cars towed by it, for the Month of.....189

Date.	Routes	REVENUE MOTOR TRIPS.											REVENUE TOWED TRIPS.										
1																							
2																							

SUMMARY OF MILEAGE.

Motor trips on Route No. @ =
" " "
" " "
" " "

Total Motor Mileage, _____

Towed trips on Route No. @ =
" " "
" " "
" " "

Total Towed Mileage, _____

*To be compiled from the conductors' reports.

CHAPTER XIII.

LEADING TYPES OF CARS ILLUSTRATED.

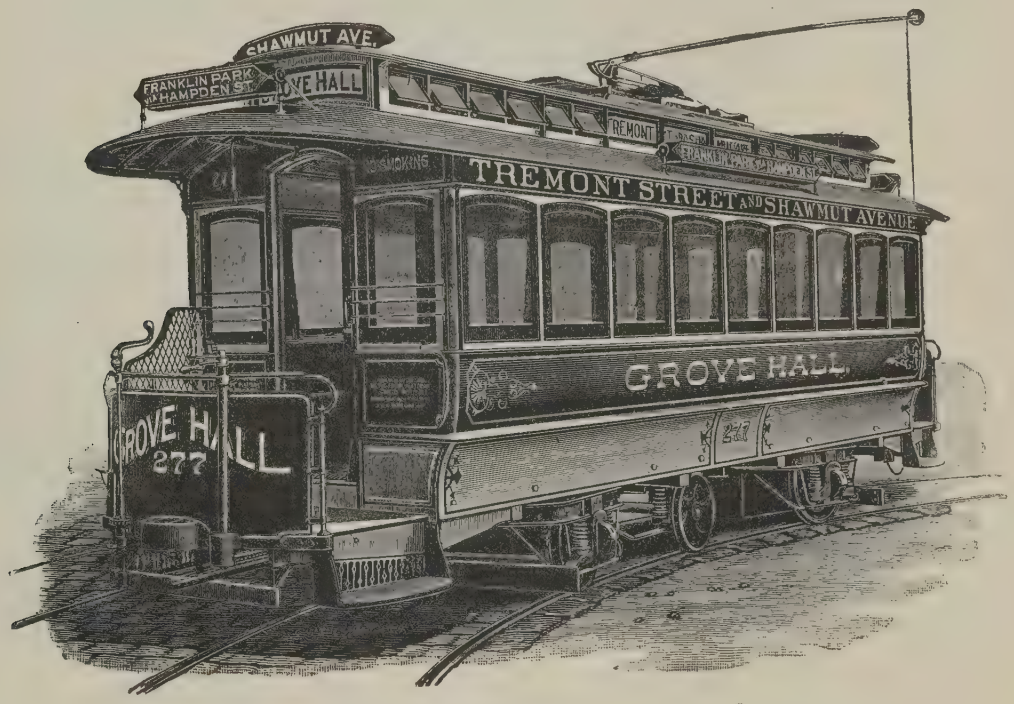


FIG. 1.—SIX WHEEL RADIAL TRUCK ELECTRIC CAR.

FIG. 2.—LONG EIGHT WHEEL ELECTRIC CAR—BOSTON TYPE.

FIG. 3.—VESTIBULE ELECTRIC CAR.

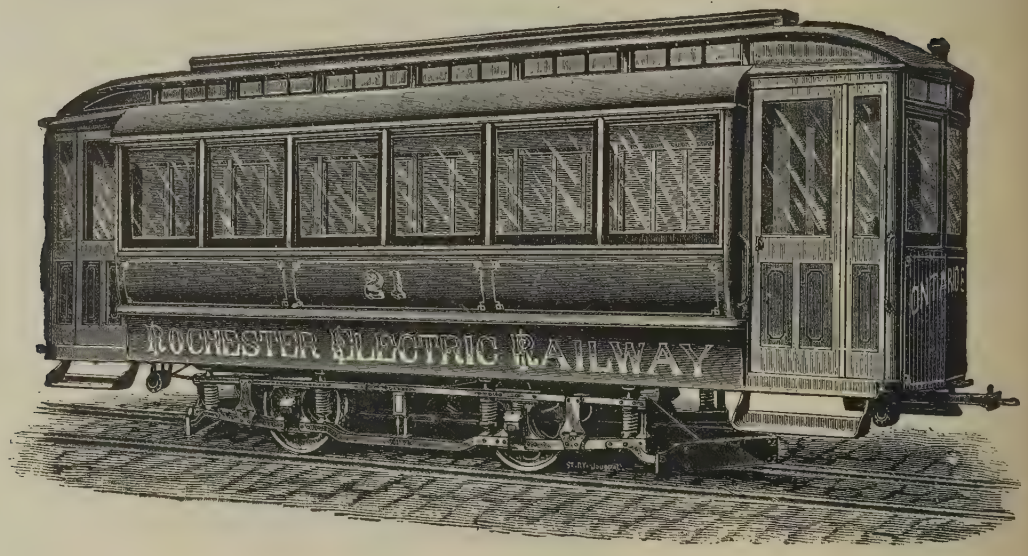


FIG. 4.—VESTIBULE ELECTRIC CAR.

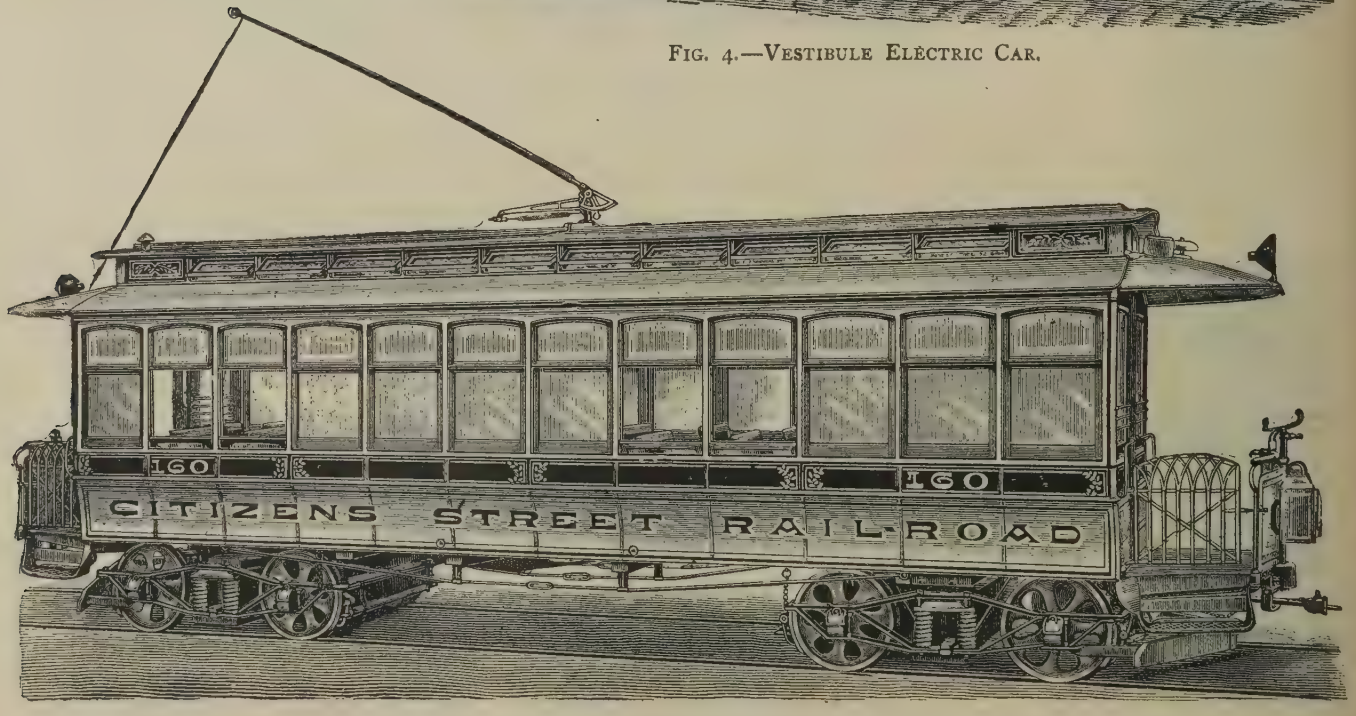


FIG. 5.—EIGHT WHEEL ELECTRIC CAR WITH CROSS SEATS.

FIG. 6.—ELECTRIC MOTOR CAR.

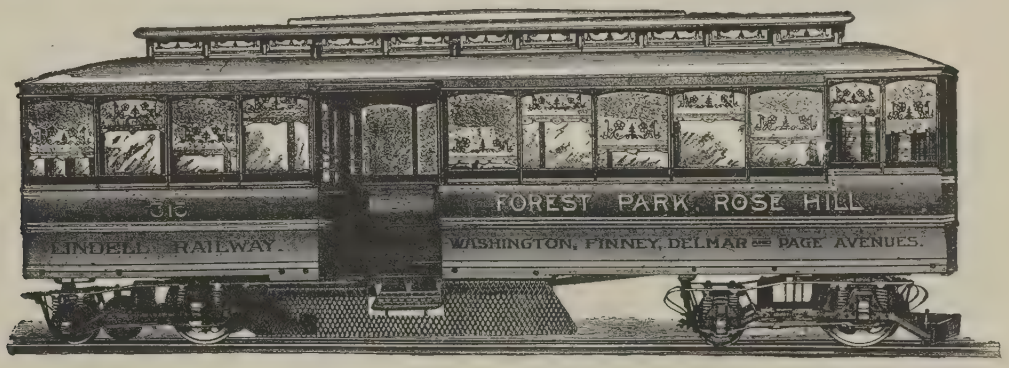


FIG. 7.—SIDE VESTIBULE EIGHT-WHEEL CAR.

FIG. 8.—ELECTRIC CAR.

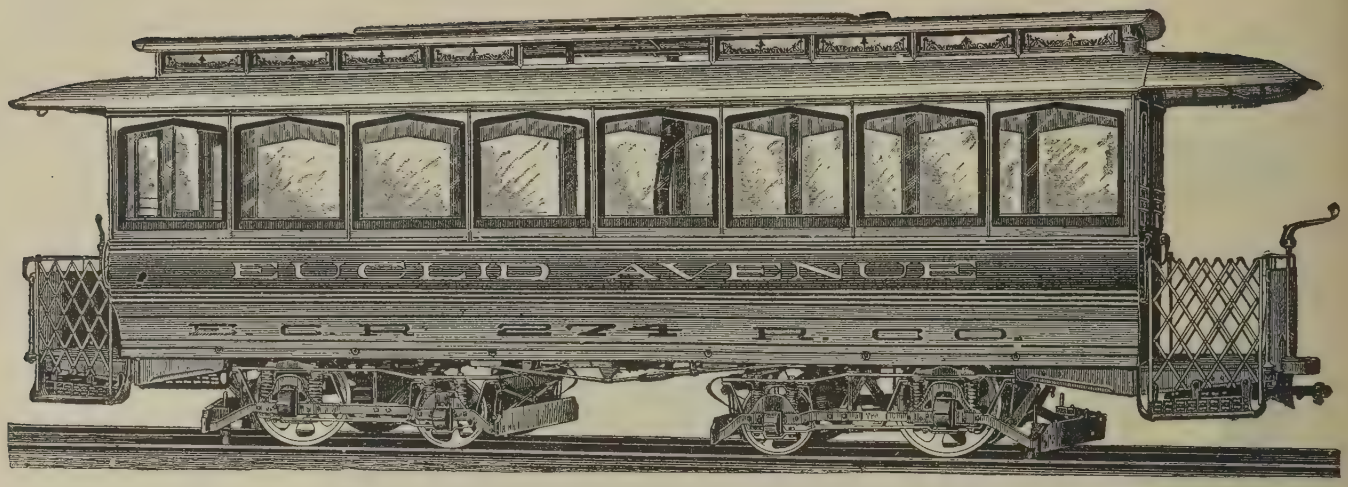


FIG. 9.—EIGHT WHEEL ELECTRIC CAR.

FIG. 10.—ELECTRIC MOTOR CAR.

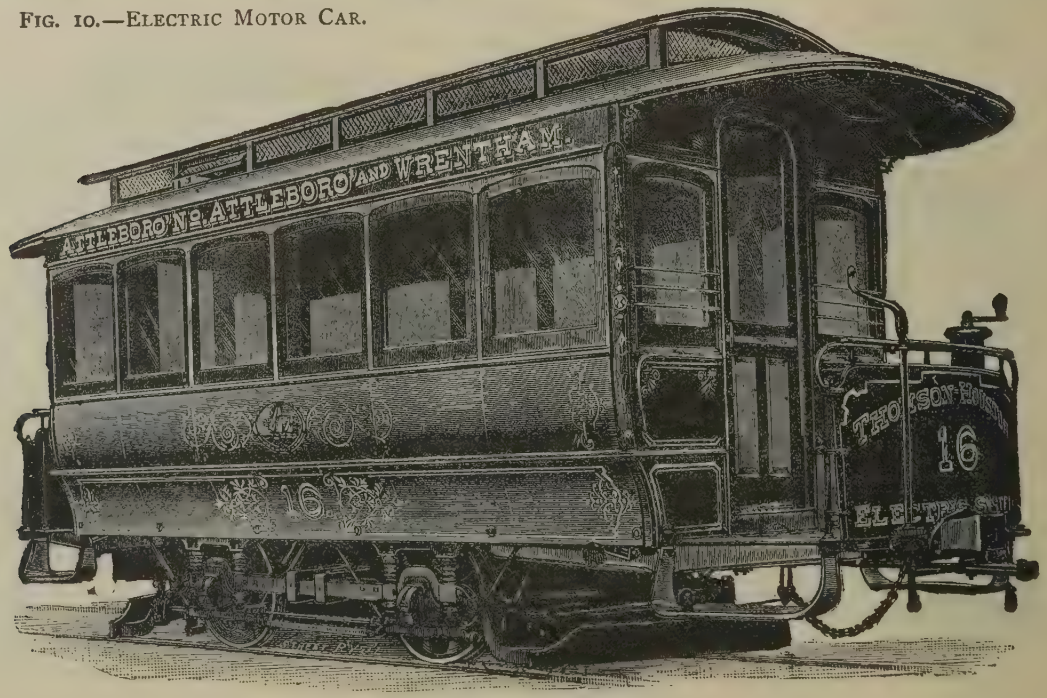


FIG. 11.—ELECTRIC MOTOR CAR.

FIG. 12.—ELECTRIC CAR.

FIG. 13.—STORAGE BATTERY CAR.

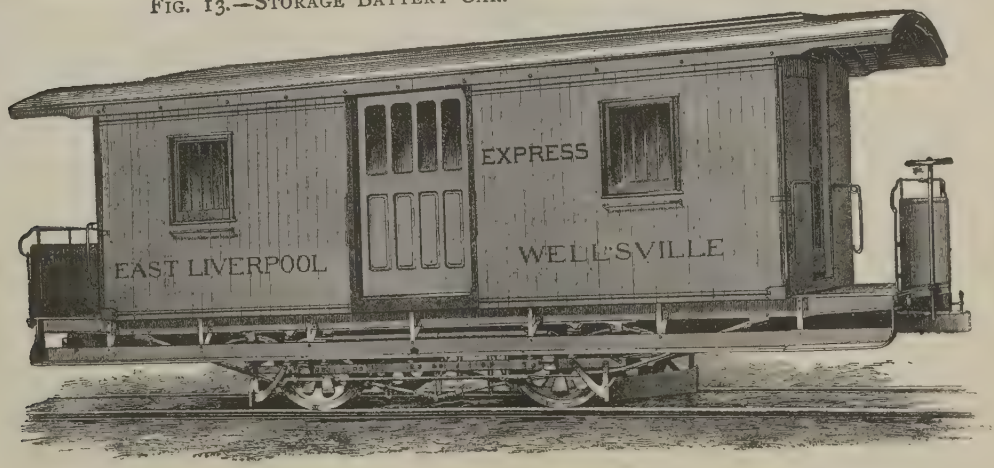


FIG. 14.—STREET RAILWAY EXPRESS CAR.

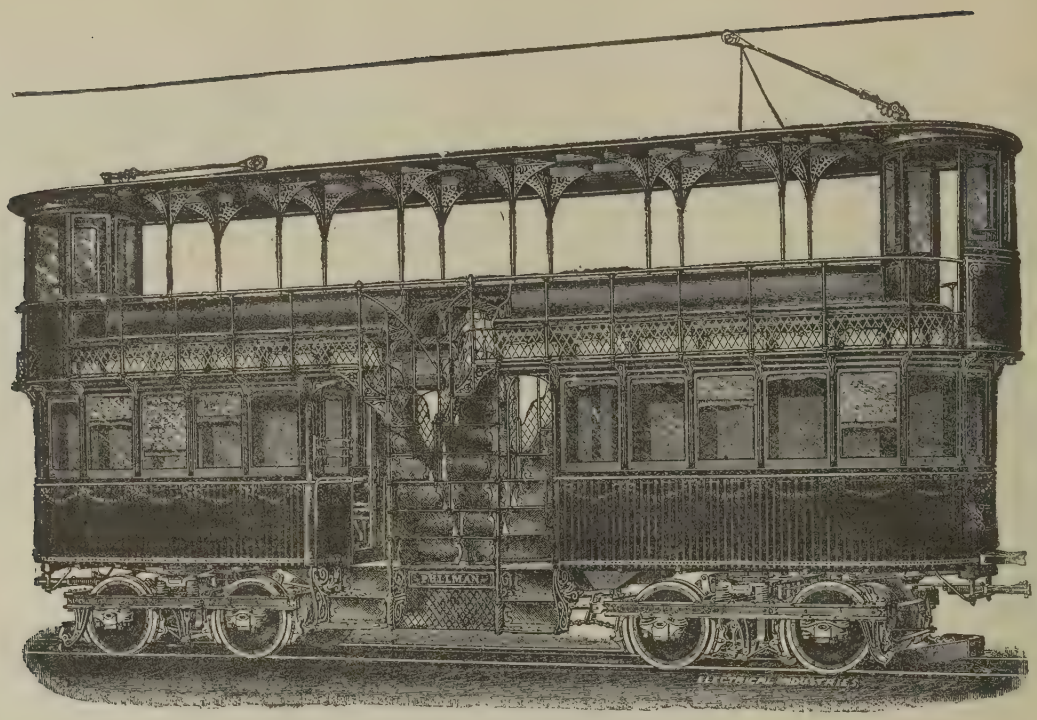


FIG. 15.—DOUBLE DECK, SIDE VESTIBULE ELECTRIC CAR.

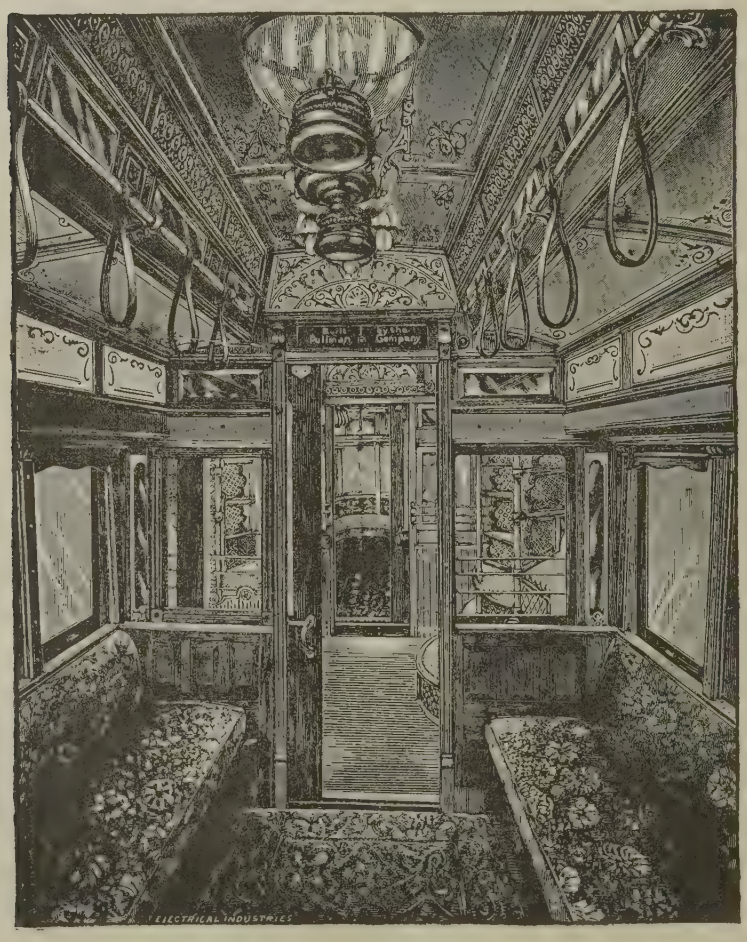


FIG. 16.—INTERIOR OF FIG. 15.

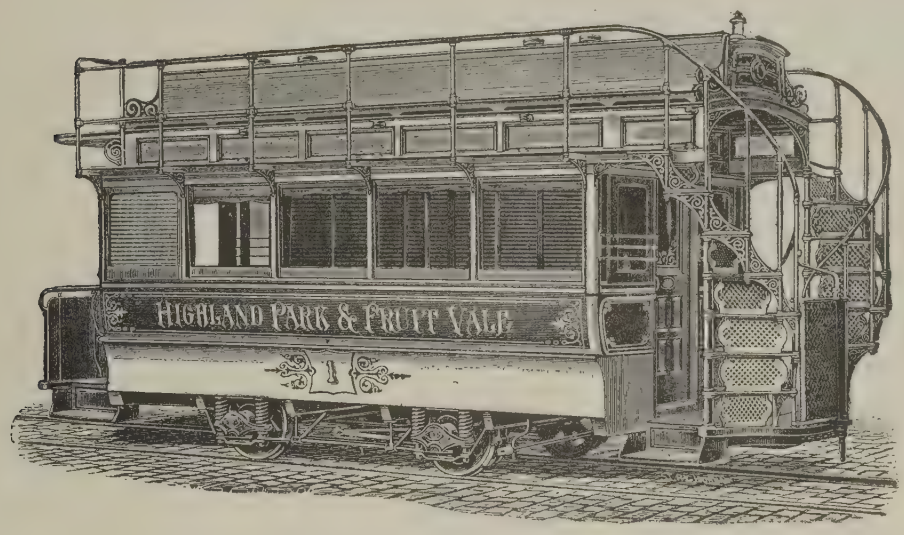


FIG. 17.—DOUBLE DECK CAR.

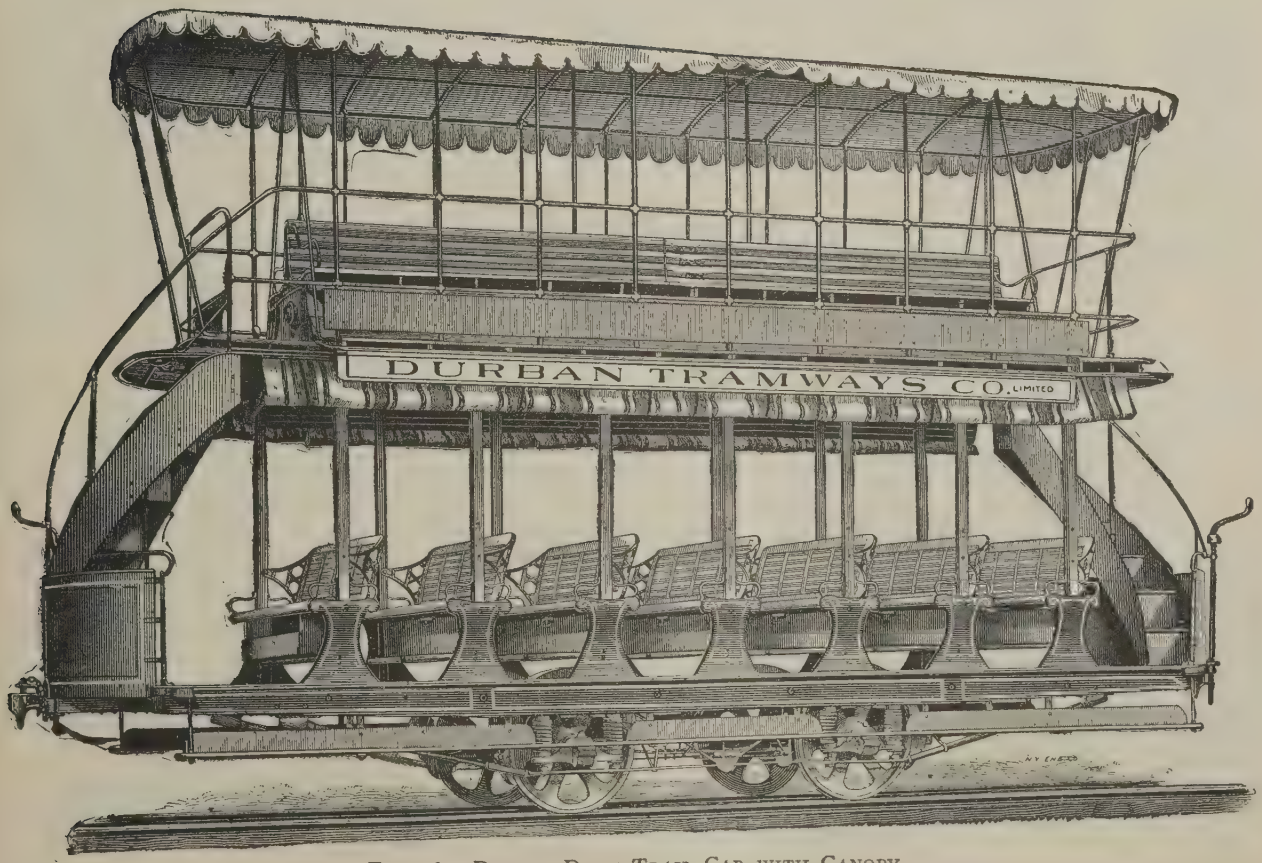


FIG. 18.—DOUBLE DECK TRAIL CAR WITH CANOPY.

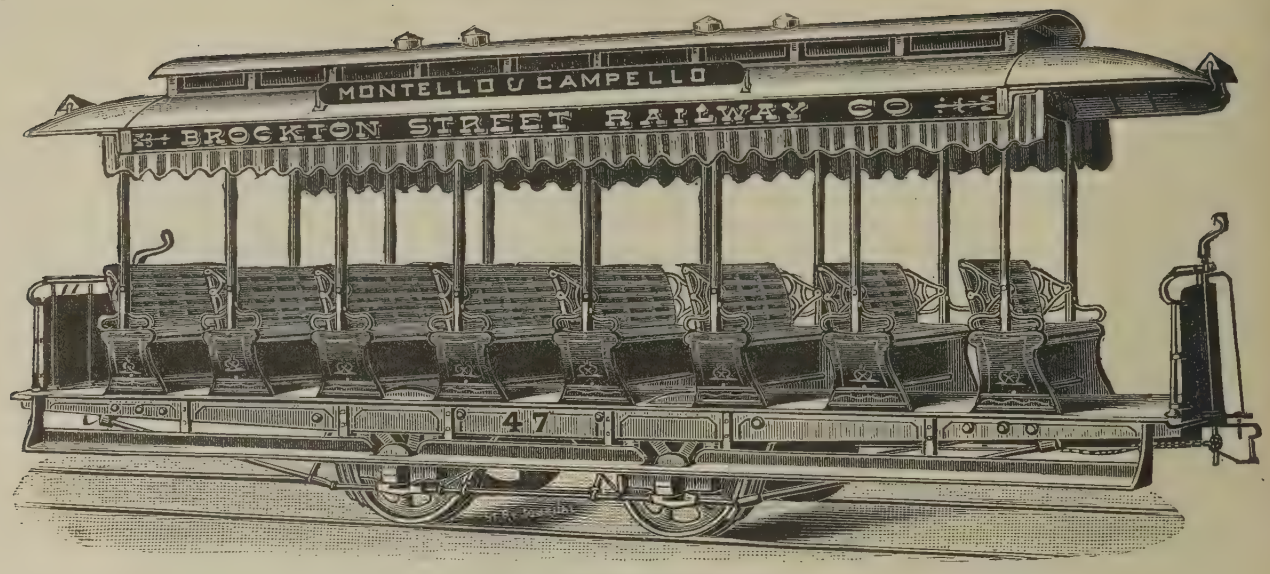


FIG. 19.—OPEN HORSE CAR.

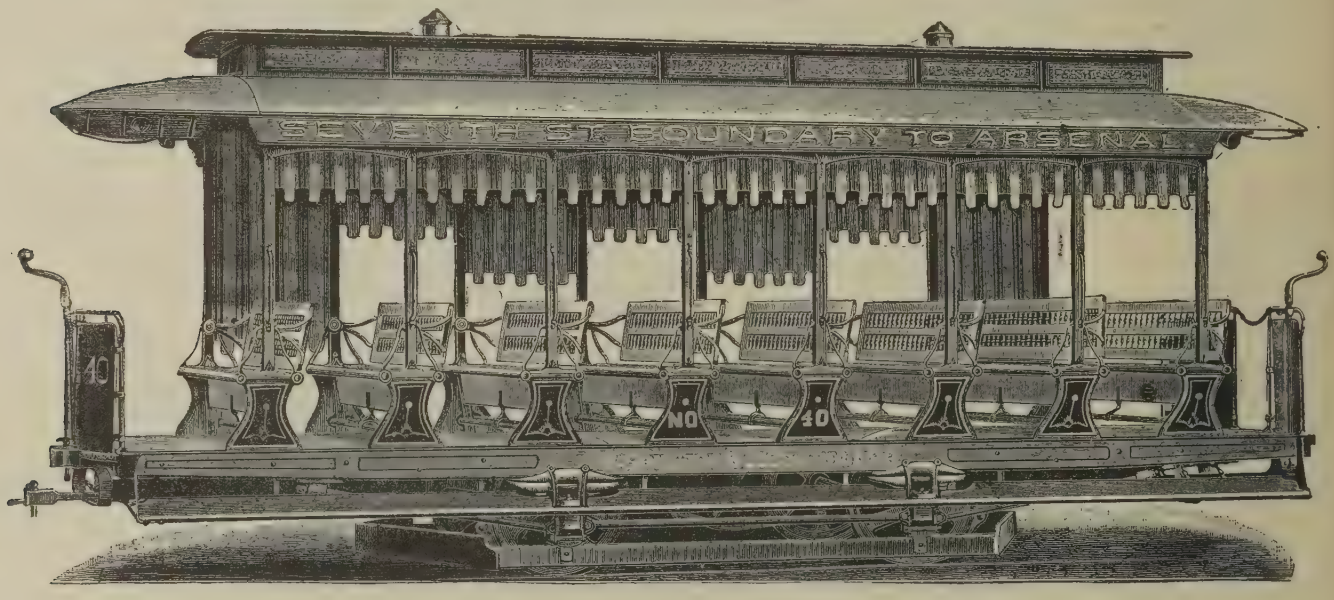


FIG. 20.—OPEN TRAIL CABLE CAR.

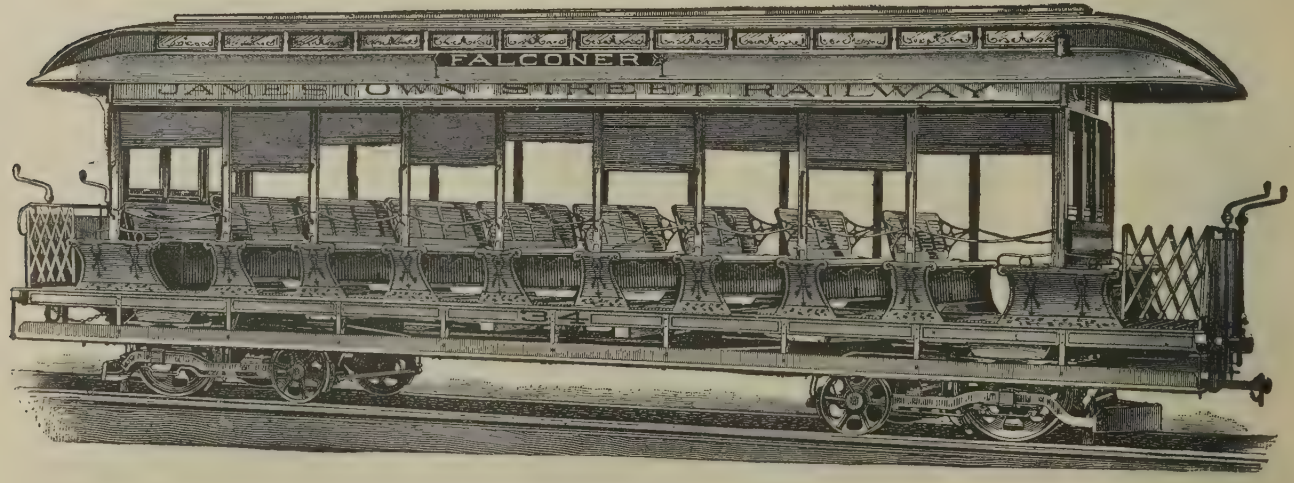


FIG. 21.—OPEN CAR WITH ROLLER CURTAINS.

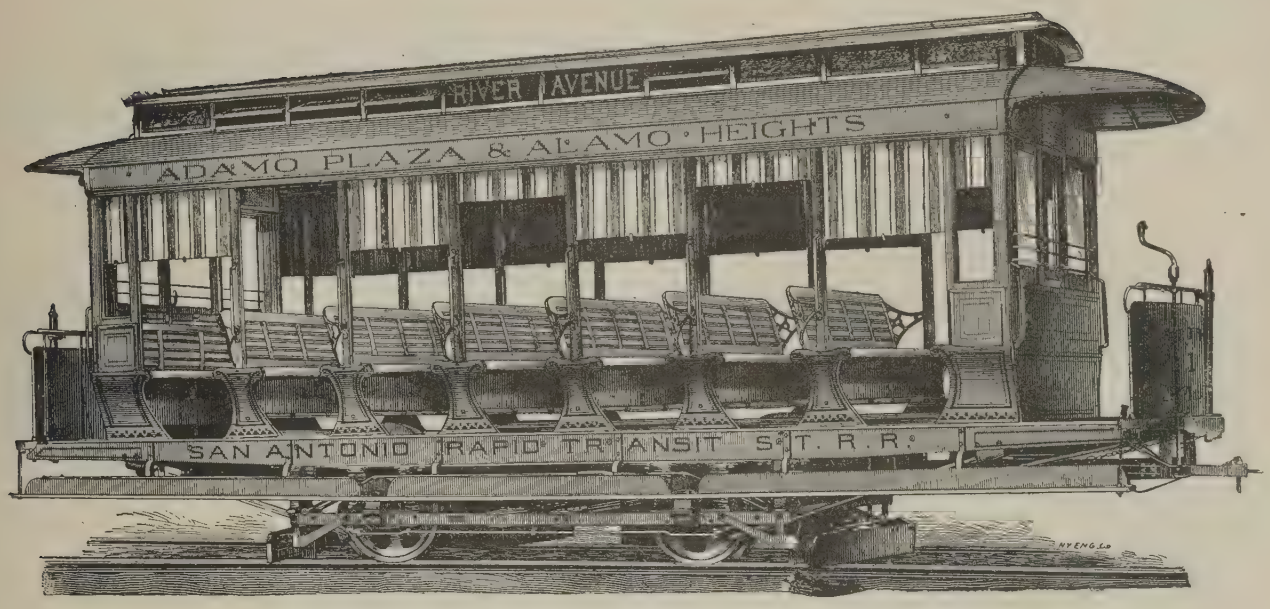


FIG. 22.—OPEN MOTOR CAR.

FIG. 23.—VESTIBULED CABLE CAR.

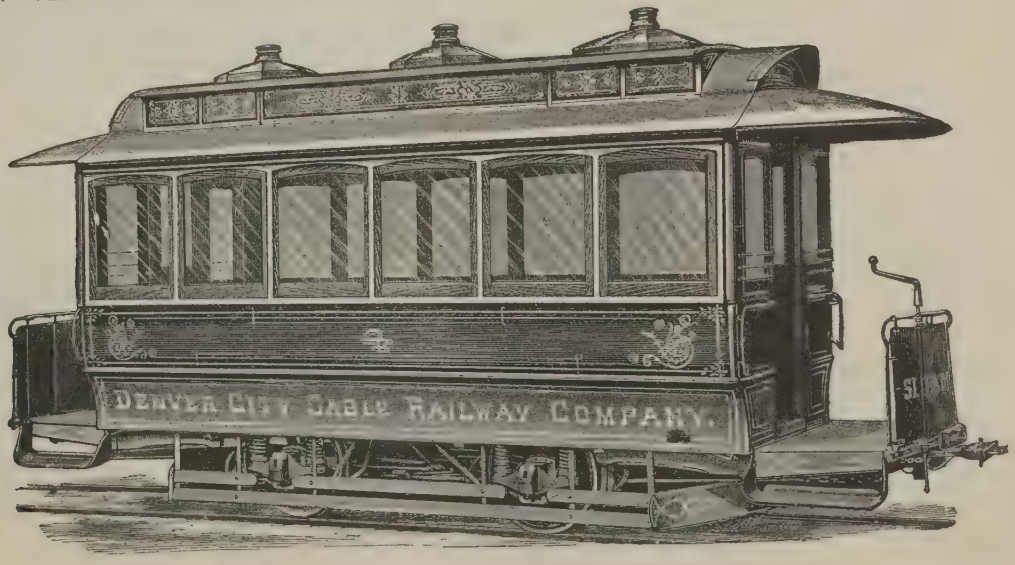


FIG. 24.—CLOSED CABLE TRAIL CAR.

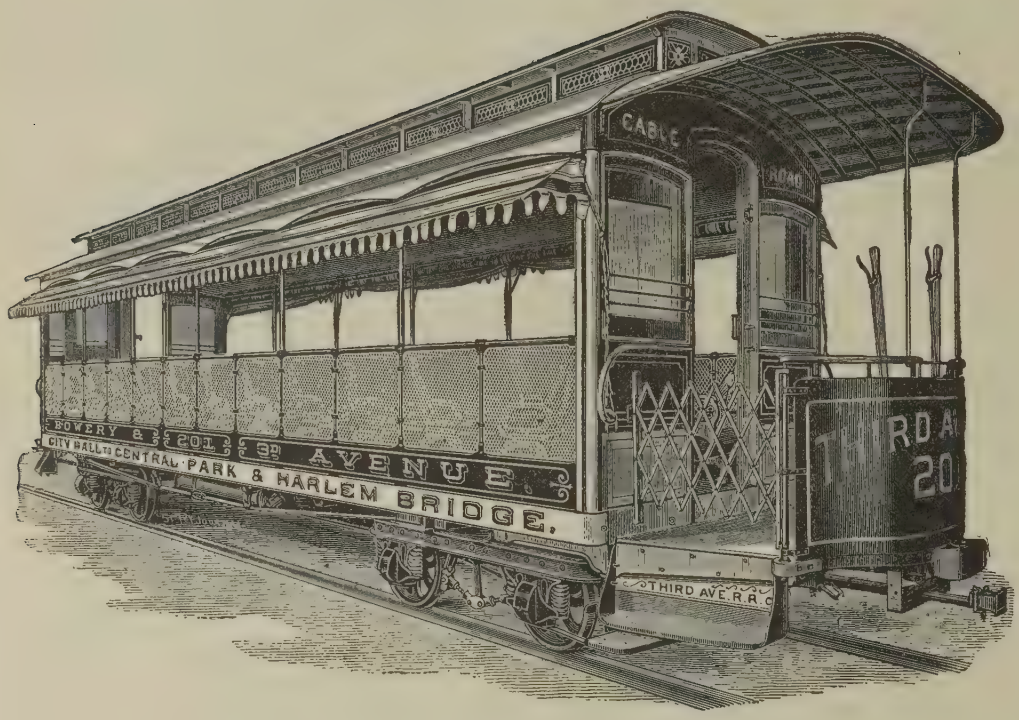


FIG. 25.—EIGHT WHEEL OPEN CABLE CAR.

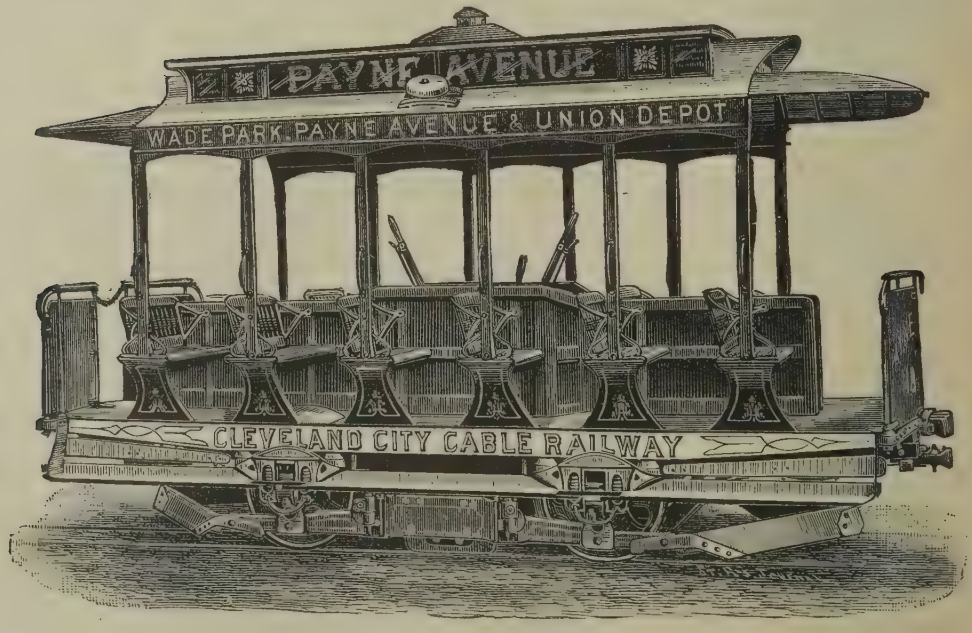


FIG. 26.—OPEN GRIP CAR.

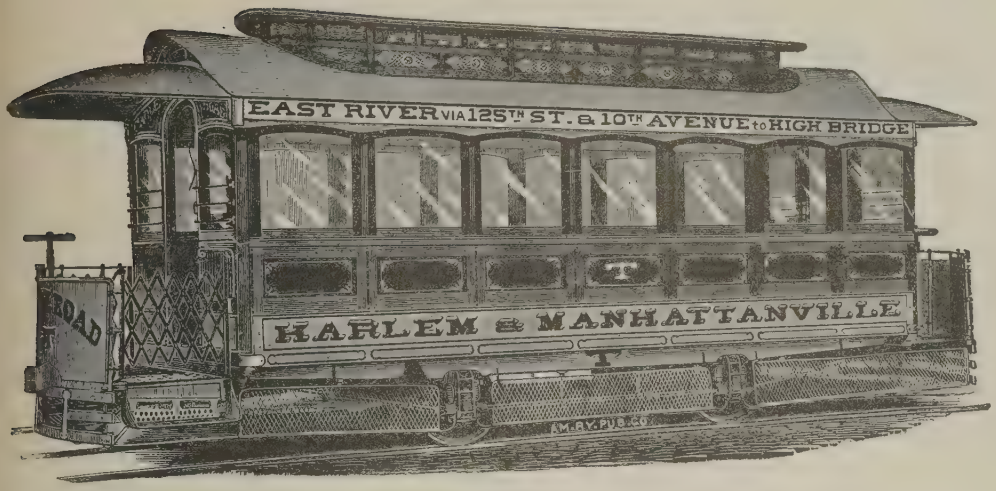


FIG. 27.—CLOSED CABLE CAR.

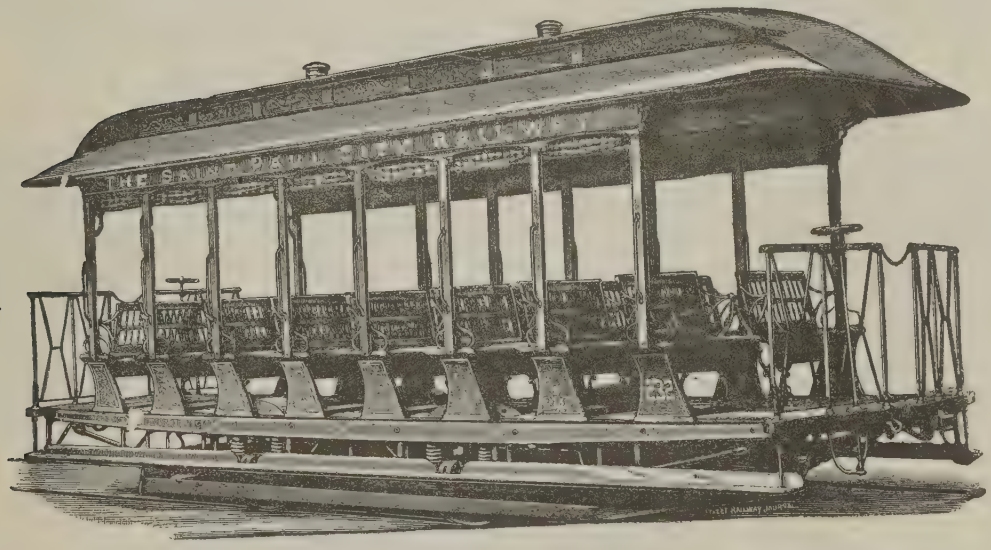


FIG. 28.—OPEN CABLE TRAIL CAR.

FIG. 29.—COMBINATION GRIP AND PASSENGER CABLE CAR.

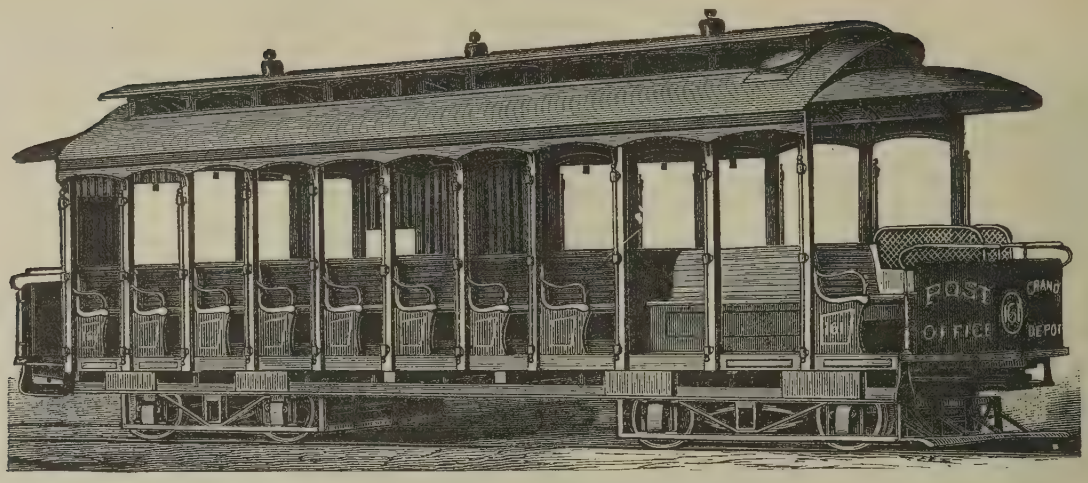


FIG. 30.—COMBINATION CABLE CAR FOR SUMMER.

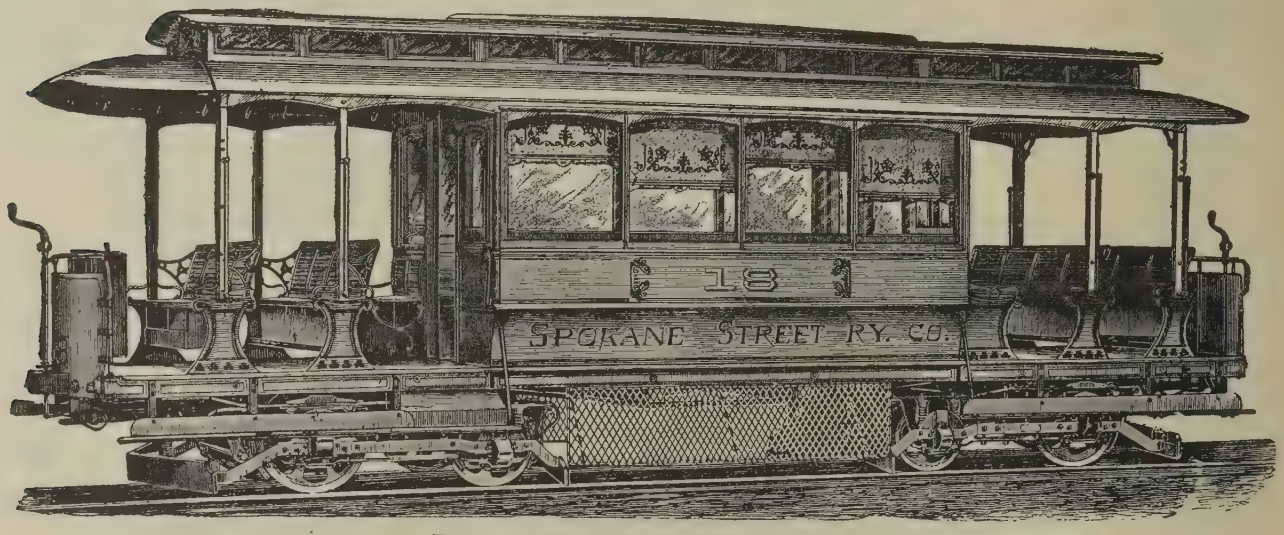


FIG. 31.—COMBINATION ELECTRIC CAR

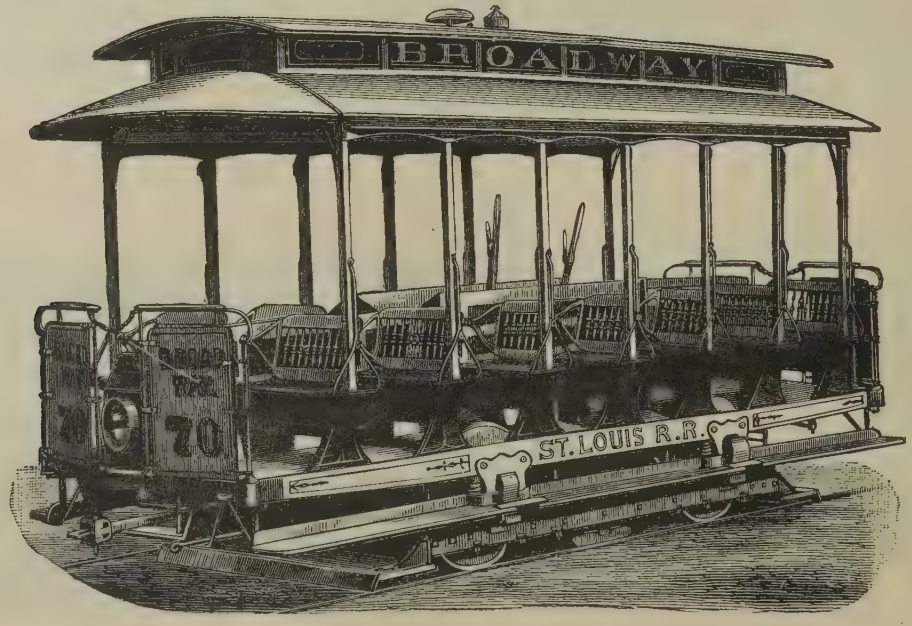


FIG. 32.—OPEN GRIP CAR.

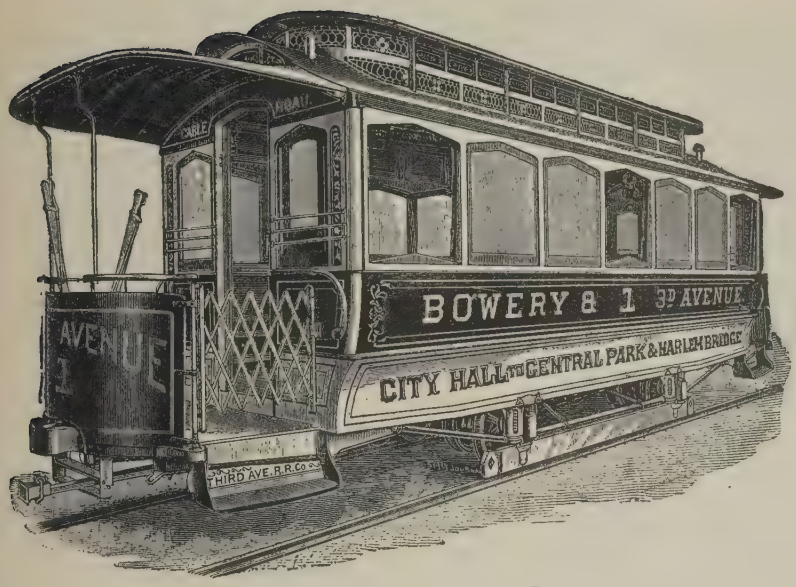


FIG. 33.—CLOSED CABLE CAR.

FIG. 34.—BOB TAIL CAR.

FIG. 35.—CLOSED TRAIL CAR.

FIG. 36.—SIXTEEN FOOT HORSE CAR.

FIG. 37.—SIXTEEN FOOT HORSE CAR.

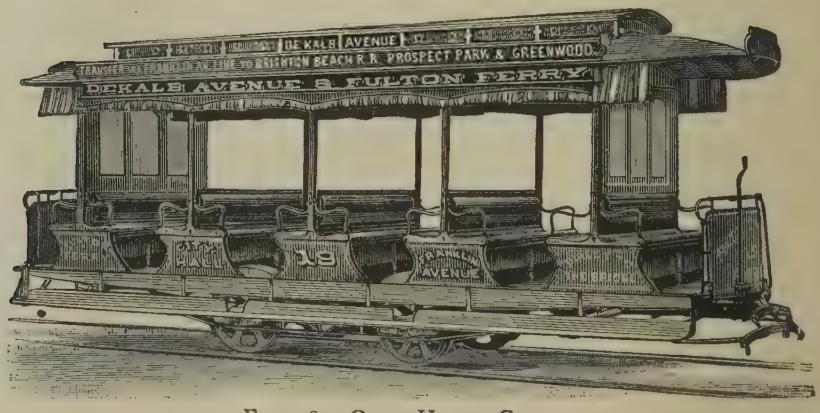


FIG. 38.—OPEN HORSE CAR.

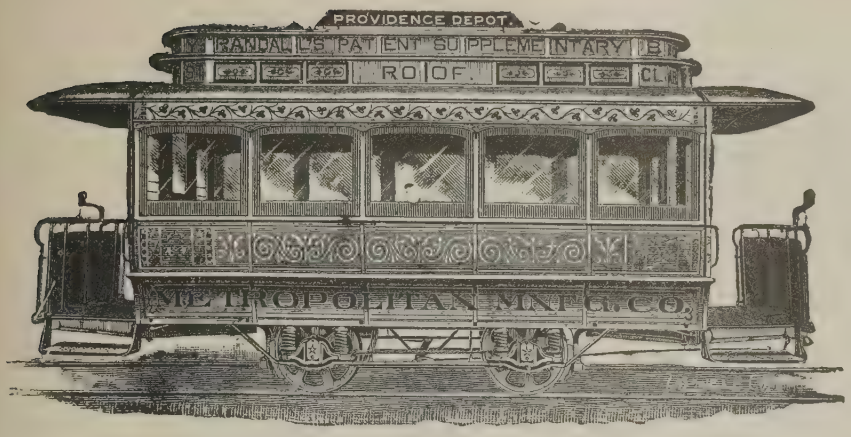


FIG. 39.—FOURTEEN FOOT HORSE CAR.

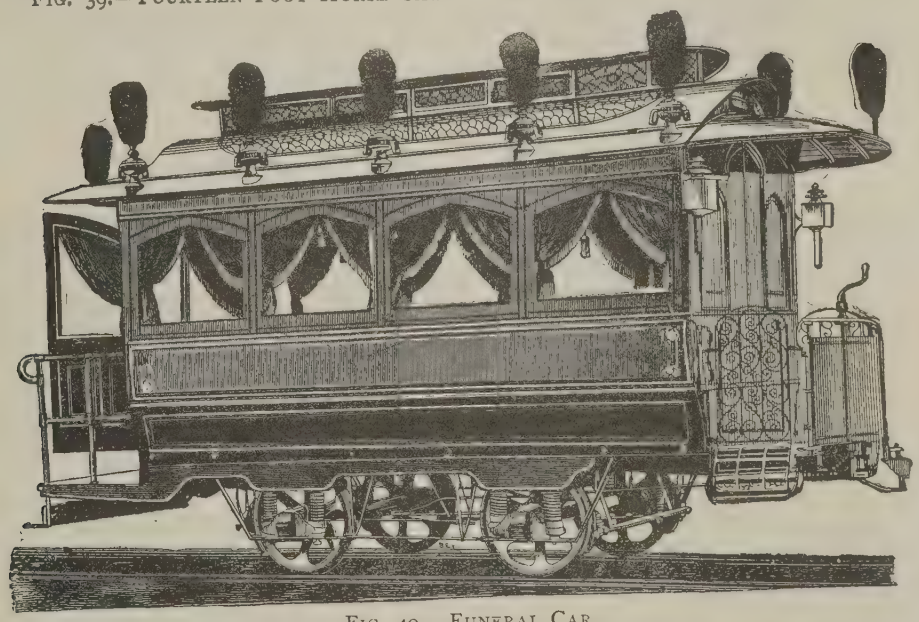


FIG. 40.—FUNERAL CAR.

FIG. 41.—SIXTEEN FOOT HORSE CAR.

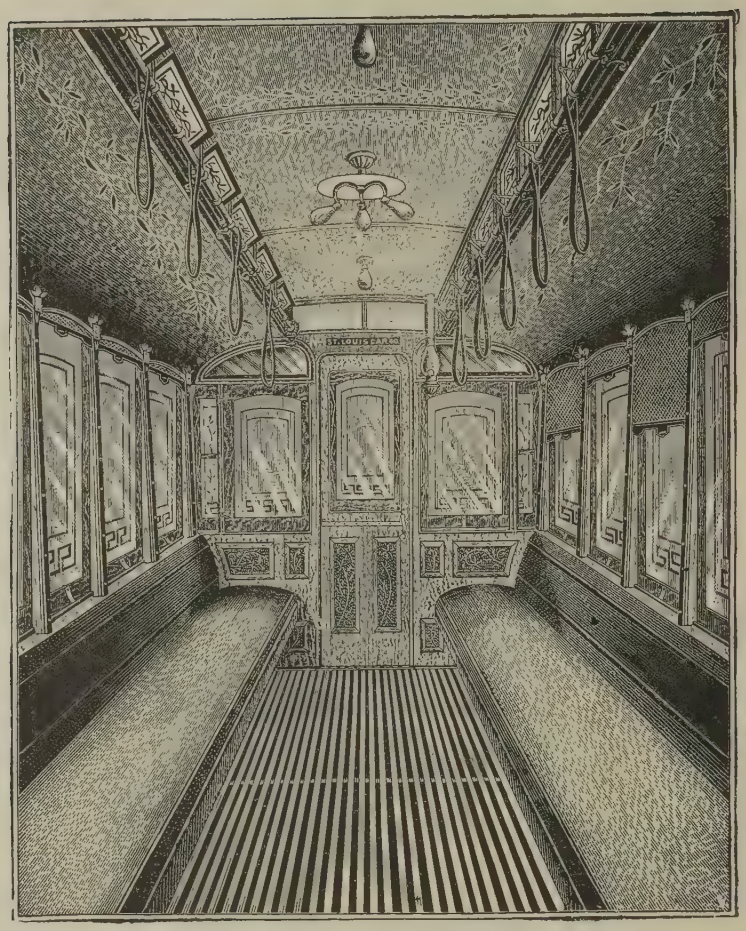


FIG. 42.—CAR INTERIOR.

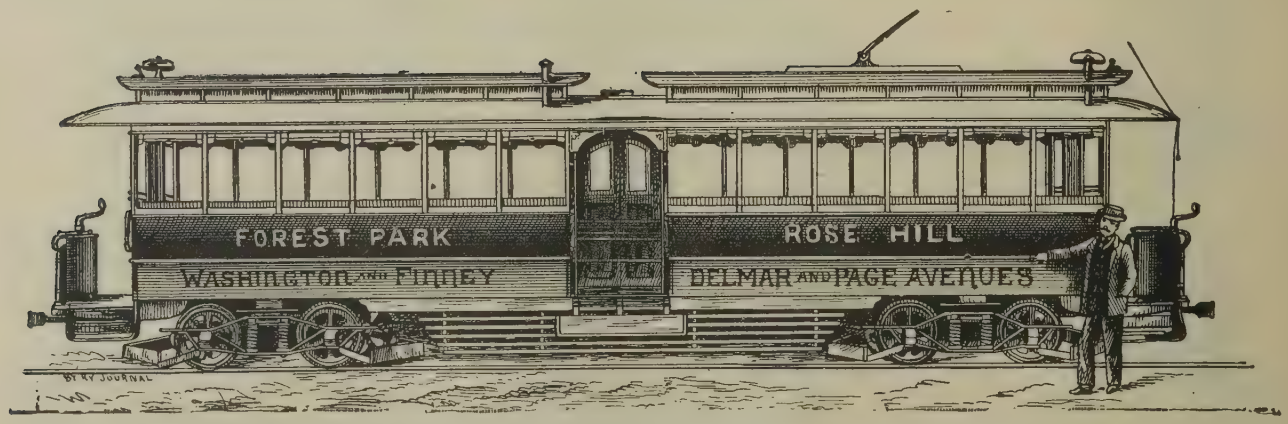


FIG. 43.—SPLICED SIDE VESTIBULE ELECTRIC CAR.

FIG. 44.

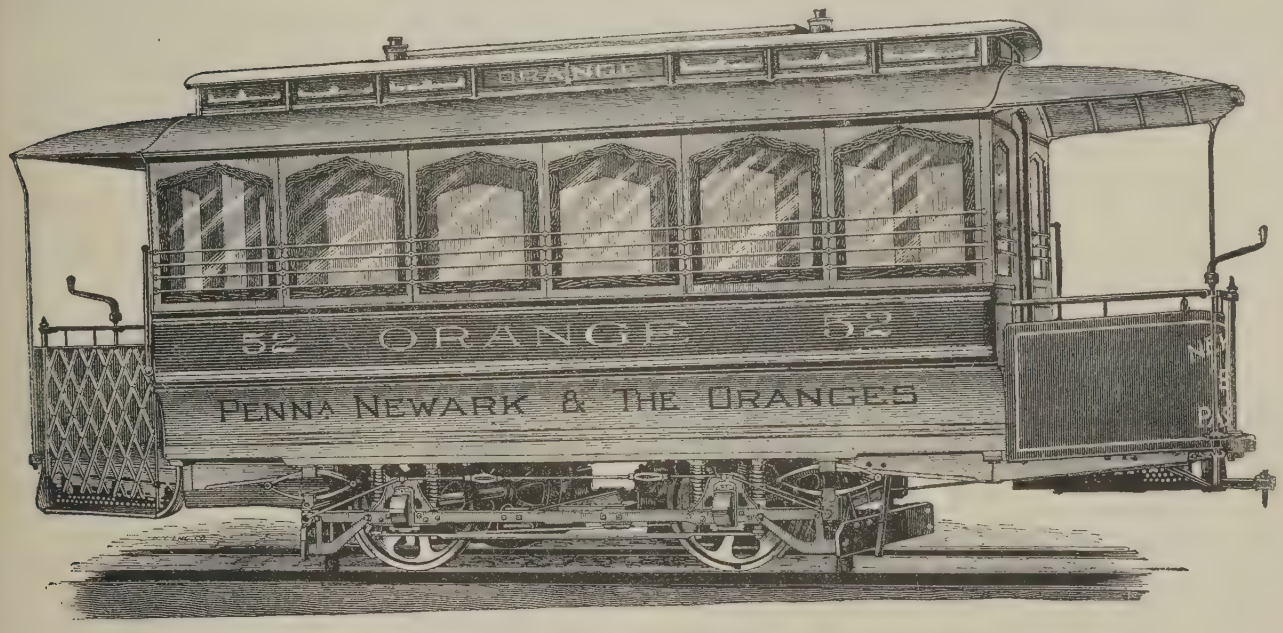


FIG. 45.—CLOSED ELECTRIC CAR WITH WINDOW GUARD RAILS.

FIG. 46.—COMBINED PASSENGER AND FREIGHT CAR.

FIG. 47.—EIGHTEEN FOOT ELECTRIC CAR.

The cars shown in the foregoing illustrations were built by the following firms. The numbers after the name refer to the corresponding figures :

AMERICAN CAR CO., St. Louis, Mo., Builders of Fig. 47.
BRILL CO., J. G., Philadelphia, Pa., Builders of Figs. 3, 5, 7, 9, 14, 18, 21, 22, 27, 31, 35, 38, 40, 45, 46.
BRIGGS CARRIAGE CO., Amesbury, Mass., Builder of Fig. 19.
BROWNELL CAR CO., St. Louis, Mo., Builders of Figs. 29, 30, 32, 34, 44.
ELLIS CAR CO., Amesbury, Mass., Builders of Fig. 11.
GILBERT CAR CO., Troy, N. Y., Builders of Fig. 4.
JONES' SONS, J. M., West Troy, N. Y., Builders of Figs. 1, 2, 20.
LACLEDE CAR CO., St. Louis, Mo., Builders of Figs. 24, 25, 28, 33.
LAMOKIN CAR WORKS, Chester, Pa., Builders of Fig. 8.
LEWIS & FOWLER MANUFACTURING CO., Brooklyn, N. Y., Builders of Fig. 41.
LINDELL RAILWAY CO., St. Louis, Mo., Builders of Fig. 43.
NEWBURYPORT CAR MANUFACTURING CO., Newburyport, Mass., Builders of Fig. 36.
PHILADELPHIA TRACTION CO., Builders of Fig. 23.
PULLMAN'S PALACE CAR CO., Pullman, Ill., Builders of Figs. 15, 16.
RANDALL, I. H., Boston, Mass., Builders of Fig. 39.
SESSIONS PASSENGER CAR CO., Chicago, Ill., Builders of Fig. 17.
STEPHENSON CO., JOHN, LIMITED, New York, Builders of Figs. 6, 10, 13, 26, 37.
ST. LOUIS CAR CO., St. Louis, Mo., Builders of Figs. 12, 42.

CHAPTER XIV.

AUXILIARY APPLIANCES.

The following illustrations represent some of the leading articles that are employed either in the construction or operation of street railways, in addition to those illustrated in previous chapters. They are not given as the only models on the market for the purposes for which they were designed, but serve to show the character of the devices which are necessary to successful operation, and of whom such appliances may be purchased. Many of them will serve as patterns after which a company may make their own designs.

In case other devices are required, or the names of other manufacturers, information can be obtained by addressing the *Street Railway Journal*.

The following firms are named as the builders of the different classes of tools and appliances. The numbers following the name indicate the figures illustrated.

American Horse Protector Co., 430 West Fourteenth Street, New York, Fig. 72.
Bakeman & Co., Frank, 6 Rotunda, Rookery, Chicago, Ill., Fig. 77.
Beadle, Edward, 1,195 Broadway, New York, Figs. 3, 5, 6, 14, 15.
Brooklyn Railway Supply Co., Stamford, Conn., Figs. 66, 71.
Brownell Car Co., St. Louis, Mo., Fig. 16.
Chicago City Railway Co., Chicago, Ill., Fig. 67.
Chicago Wood Mat Co., 247 North Wells Street, Chicago, Ill., Fig. 17.
Davis & Cook, Watertown, N. Y., Figs. 37, 38.
Day, Augustus, 71 State Street, Detroit, Mich., Figs. 43, 65.
Dayton Manufacturing Co., Dayton, O., Figs. 42, 44.
Dry Dock, East Broadway & Battery Railway Co., New York, Fig. 99.
Dudgeon, Richard, 24 Columbia Street, New York, Figs. 55, 58, 59, 61.
Ellis Car Co., Amesbury, Mass., Fig. 64.
Falls Rivet & Machine Co., Cuyahoga Falls, O., Fig. 101.
Frost Veneer Seating Co., 206 Canal Street, New York, Fig. 102.
Fulton Foundry Co., 202 Merwin Street, Cleveland, O., Fig. 39.
Harris, Wm., & Co., 44 Broadway, New York, Fig. 86.
Hill Clutch Works, Cleveland, O., Fig. 100.
Lewis & Fowler Manufacturing Co., Brooklyn, N. Y., Figs. 2, 36, 40, 62.
Lima Register Co., Lima, O., Fig. 4.
Masson, Milton I., 109 West Twelfth Street, New York, Fig. 11.
Millers Falls Co., 93 Reade Street, New York, Figs. 96, 97.
Meaker Manufacturing Co., Chicago, Ill., Fig. 7.
Moseman, C. M., & Bro., 128 Chambers Street, New York, Fig. 74.
New Departure Bell Co., Bristol, Conn., Fig. 41.
New York Steel Mat Co., 234 Broadway, New York, Figs. 12, 13.
Perfection Oil Purifying Co., 136 Liberty Street, New York, Fig. 79.
Pittsburgh Steel Hollow Ware Co. (Ltd.), Pittsburgh, Pa., Fig. 47.
Railway Equipment Co., Chicago, Ill., Figs. 76, 78, 80, 87, 88, 90, 92, 93, 95.
Reliable Manufacturing Co., 53 State Street, Boston, Mass., Fig. 35.
Ross, E. M. Co., Springfield, O., Fig. 82, 83.
Smith, Josephine D., 350 Pearl Street, New York, Figs. 22, 23, 24, 25, 26, 27, 29, 30, 31, 34.
Standard Index & Register Co., New York, Fig. 8.
Steam Gauge & Lantern Co., Syracuse, New York, Figs. 20, 21, 28, 32, 33.
The Q & C. Co., 703 Phœnix Building, Chicago, Ill., Fig. 73.
St. Louis Car Co., St. Louis, Mo., Fig. 9.
Third Avenue Railway Co., New York, Figs. 69, 70.
Thomson-Houston Electric Co., Boston, Mass., Fig. 63.
Tilden, B. E., & Co., Cleveland O., Fig. 48.
Toffler, A., 211 East Twenty-second Street, New York, Figs. 18, 19.
Tucker, C. H., Jr., & Bro., 129 Liberty Street New York, Fig. 75.
United Tramway Sprinkler Co., Louisville, Ky., Fig. 68.
Wales Manufacturing Co., Syracuse N. Y. Fig. 10.
Watson & Stillman, 204 East Forty-third Street, New York, Figs. 49, 50, 51, 22, 53, 54, 56, 60.
Wharton, Wm., Jr., & Co., Twenty-fifth Street & Washington Avenue, Philadelphia, Pa., Figs. 1, 89.
Wood & Fowler, Los Angeles, Cal., Fig. 45.
White, Edward C., 556 West Thirty-fourth Street, New York, Figs. 64a, 98.

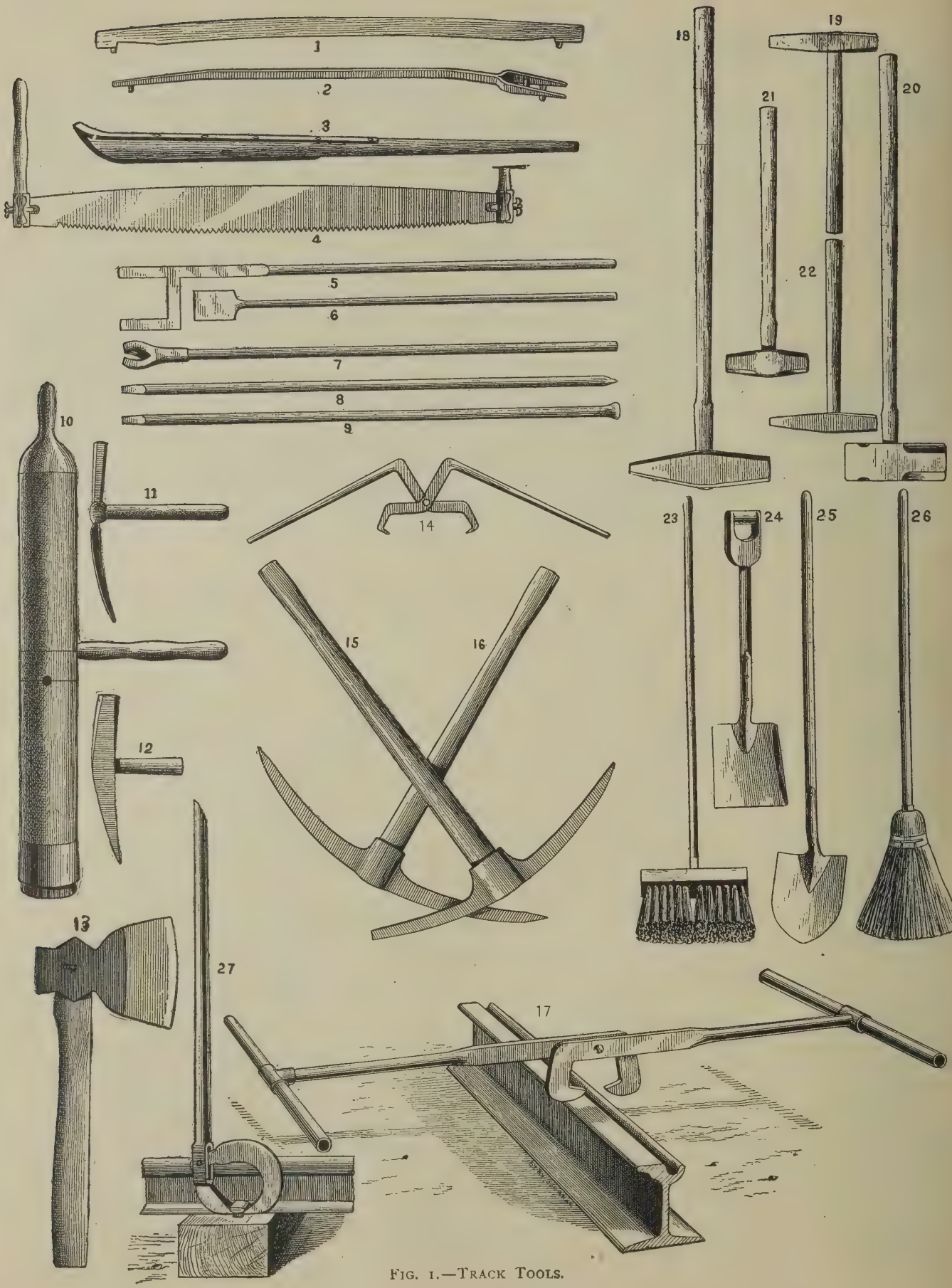


FIG. 1.—TRACK TOOLS.

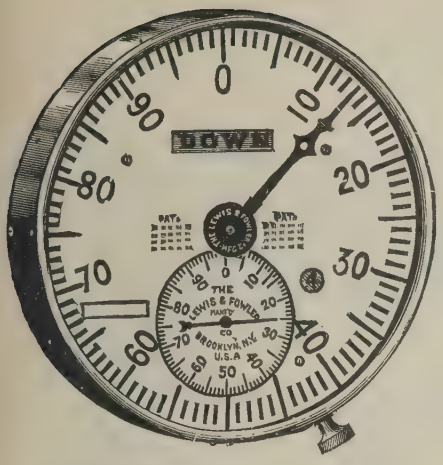


FIG. 2.—STATIONARY REGISTER.

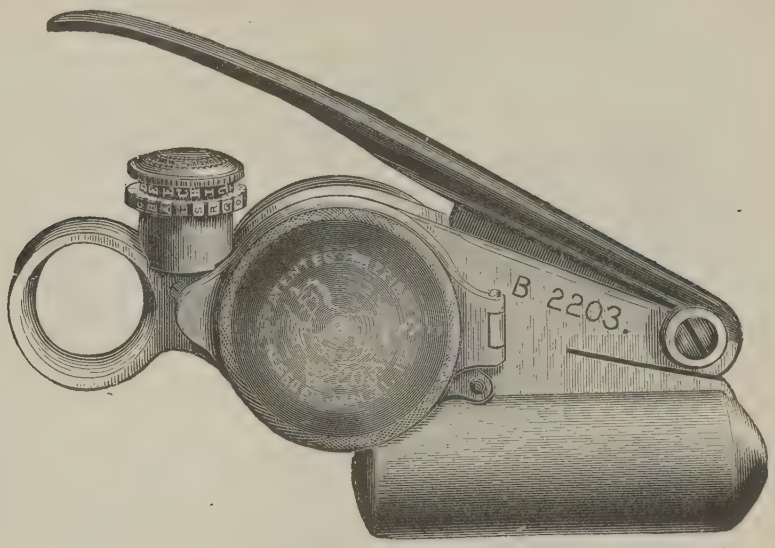


FIG. 5.—ALARM REGISTER PUNCH.

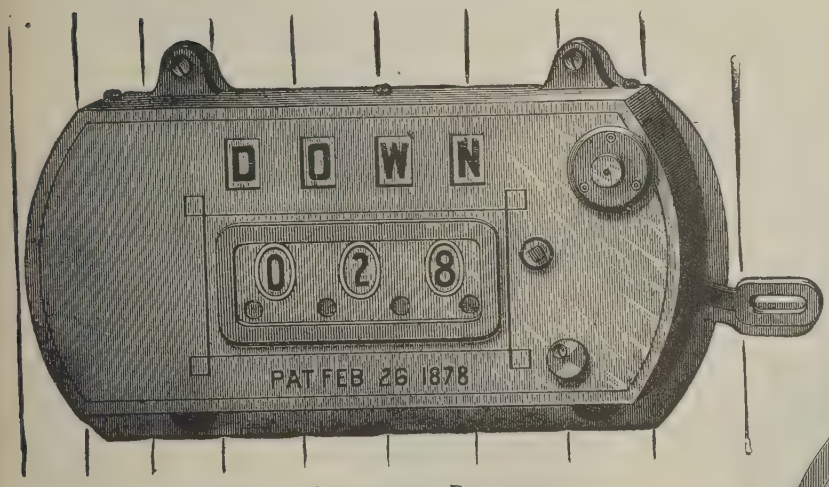


FIG. 3.—STATIONARY REGISTER.

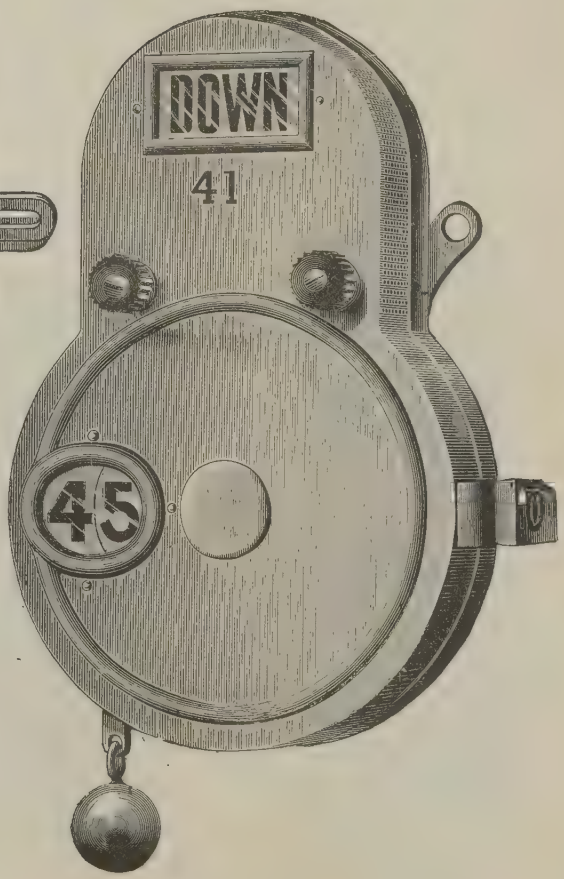


FIG. 6. PORTABLE ALARM REGISTER.

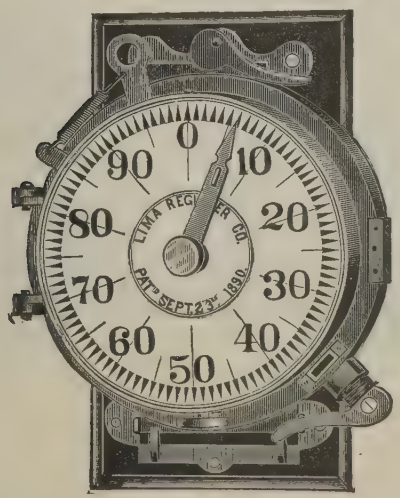


FIG. 4.—STATIONARY REGISTER.

FIG. 7.—PORTABLE REGISTER.

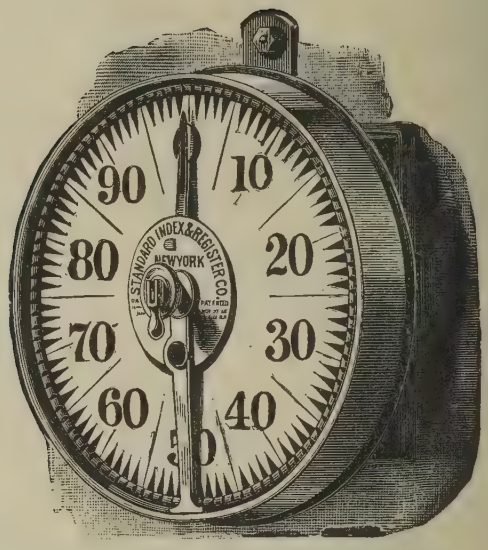


FIG. 8.—STATIONARY REGISTER.

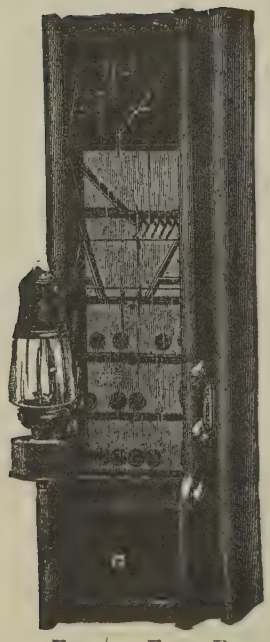


FIG. 9.—FARE BOX.

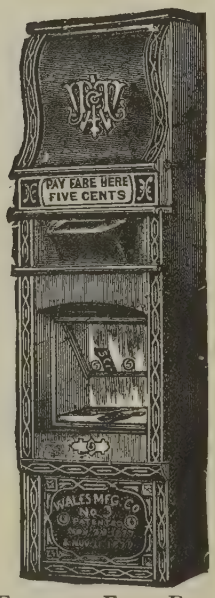
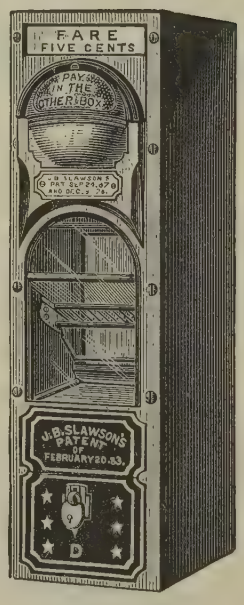
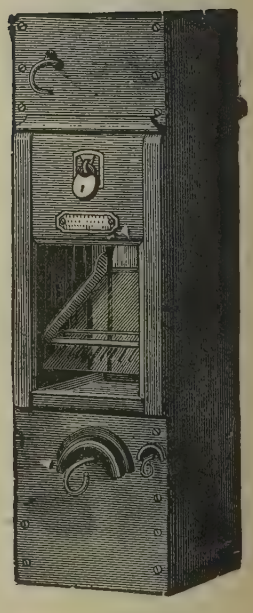


FIG. 10.—FARE BOX.



FRONT VIEW.



BACK VIEW.

FIG. 11.—FARE BOX.

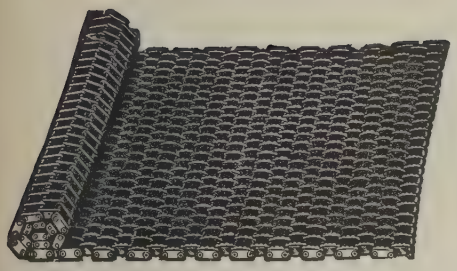


FIG. 12.—WIRE MAT.

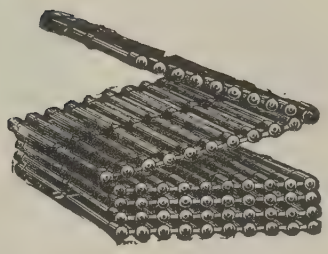


FIG. 15.—FOLDING WOOD MAT.

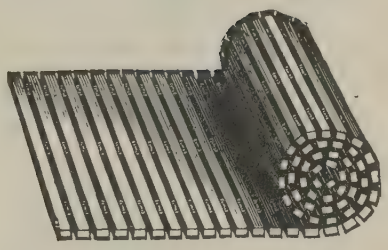


FIG. 18.—ROLLING WOOD MAT.

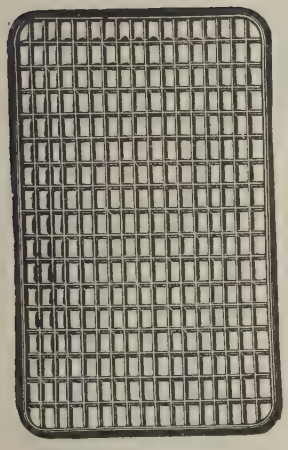


FIG. 13.—RUBBER MAT.

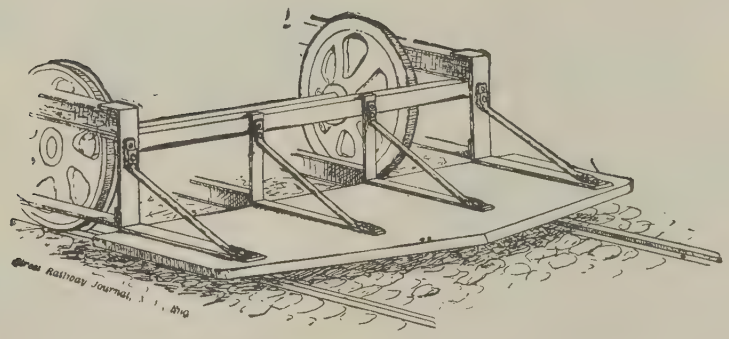


FIG. 16.—FENDER.

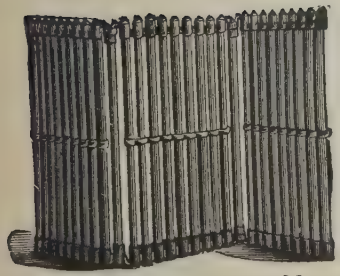


FIG. 14.—FOLDING WOOD MAT.

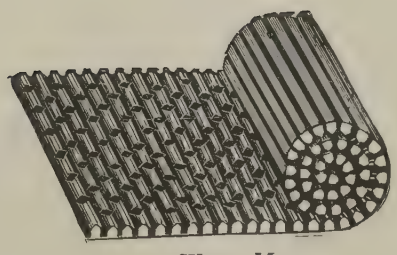


FIG. 17.—WOOD MAT.

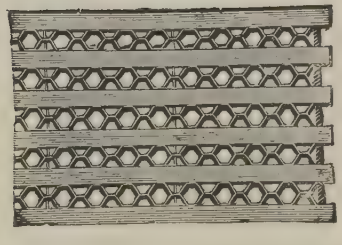


FIG. 19.—WOOD AND STEEL STRIP MAT.

FIG. 20.—HEAD LIGHT.

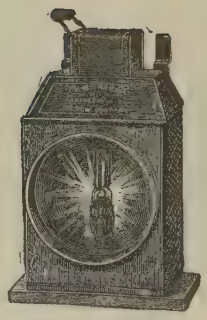


FIG. 24.—HEAD LIGHT.

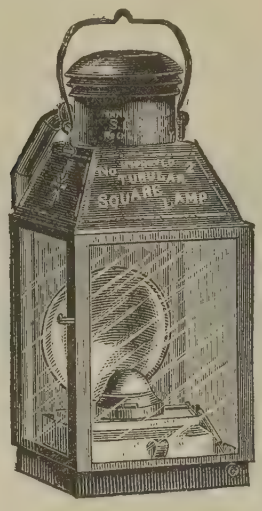


FIG. 28.—TUBULAR SQUARE LAMP.

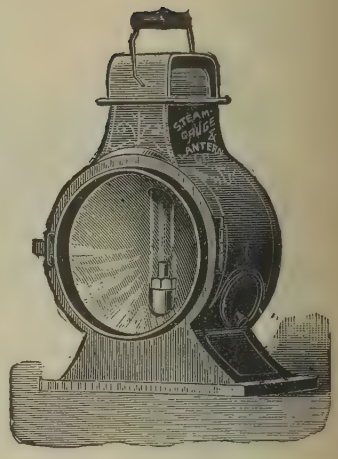


FIG. 32.—HEAD LIGHT.

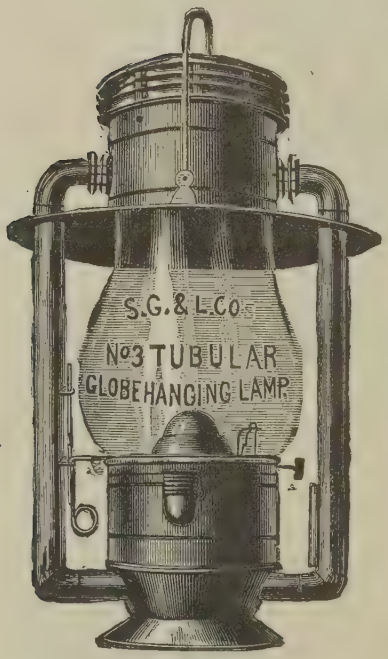


FIG. 21.—HANGING LAMP.

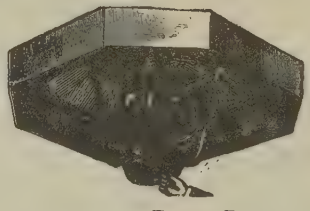


FIG. 25.—DOME REFLECTOR.

FIG. 29.—DOME REFLECTOR.

FIG. 33.—LANTERN.

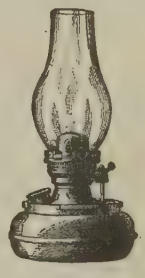


FIG. 26.—BOX LAMP.

FIG. 30.—COMBINED ELECTRIC AND OIL LAMP.

FIG. 22.—TWO GROUP LAMP.

FIG. 23.—THREE GROUP LAMP.

FIG. 27.—DOME LIGHT.

FIG. 31.—COMBINED ORNAMENTAL LAMP.

FIG. 34.—HEAD LIGHT.

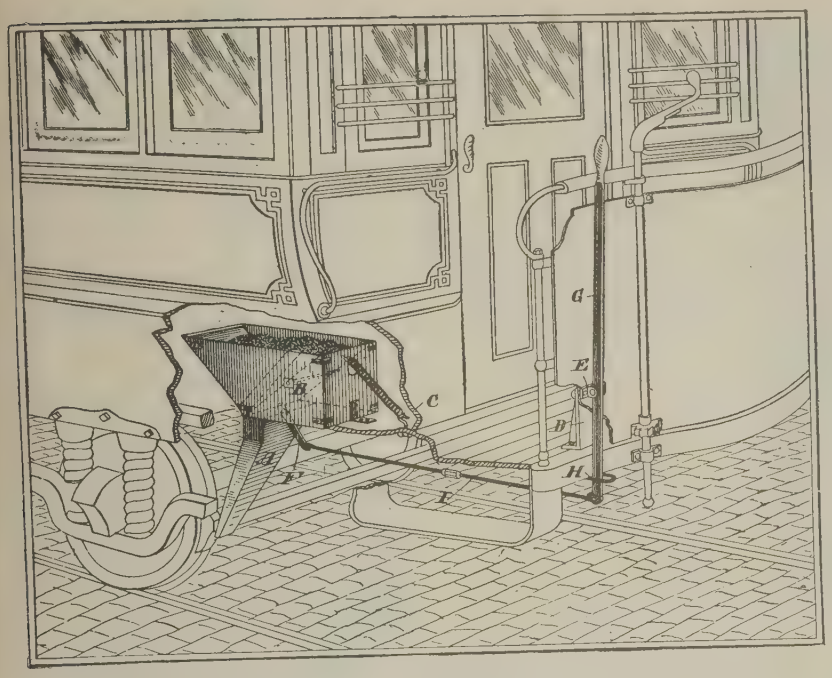


FIG. 35.—RELIABLE SAND BOX.

FIG. 39.—DOOR CLOSER.

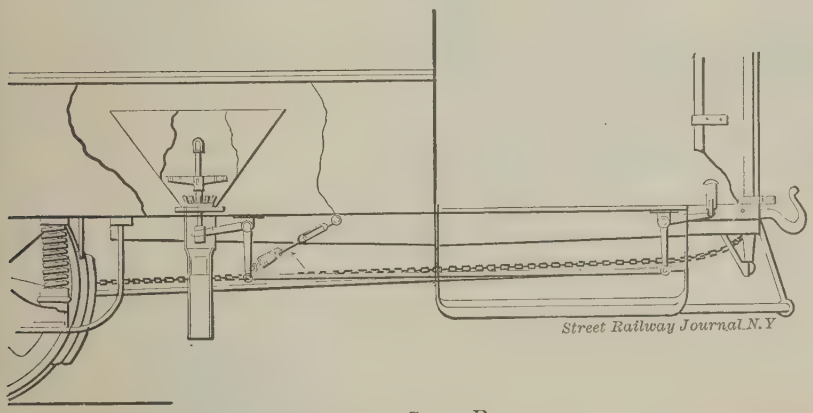


FIG. 36.—SAND BOX.

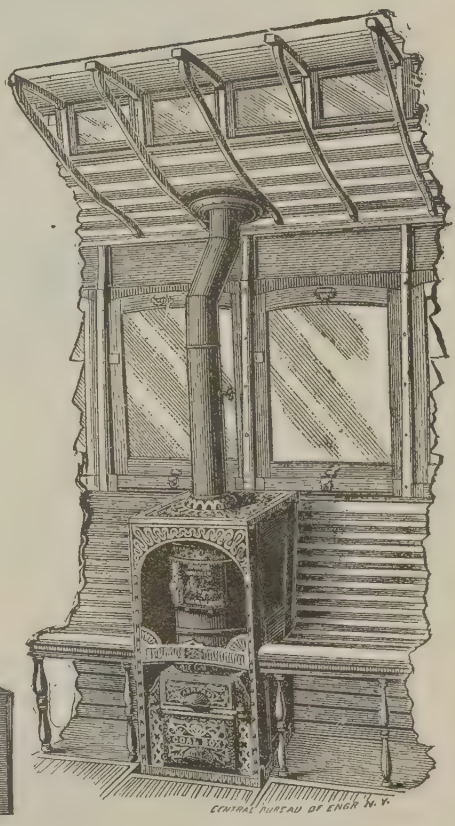


FIG. 40.—CAR HEATER.

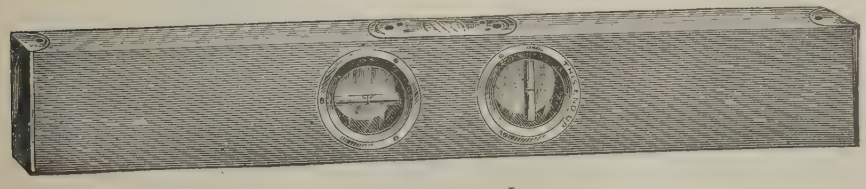


FIG. 37.—TRACK LEVEL.

FIG. 38.—TRACK LEVEL.

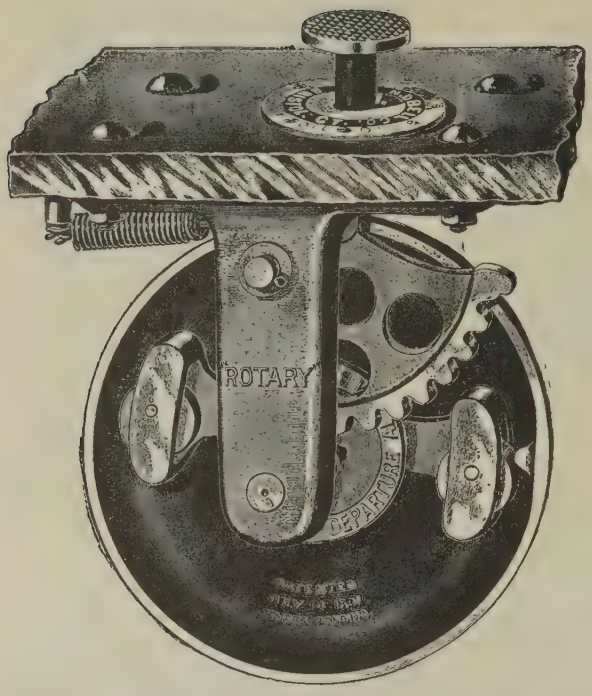


FIG. 41.—NEW DEPARTURE CENTRIFUGAL ALARM BELL.

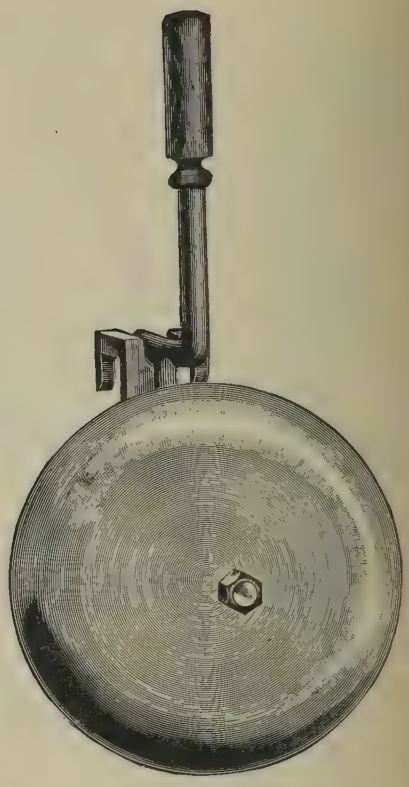


FIG. 44.—DASH GONG.

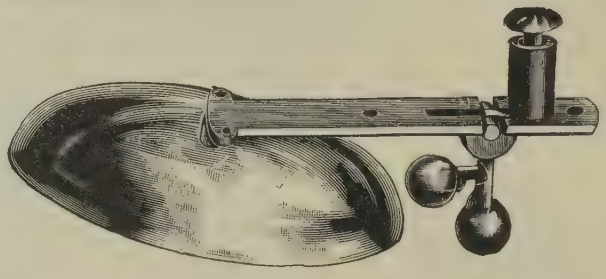


FIG. 42.—PLATFORM GONG.

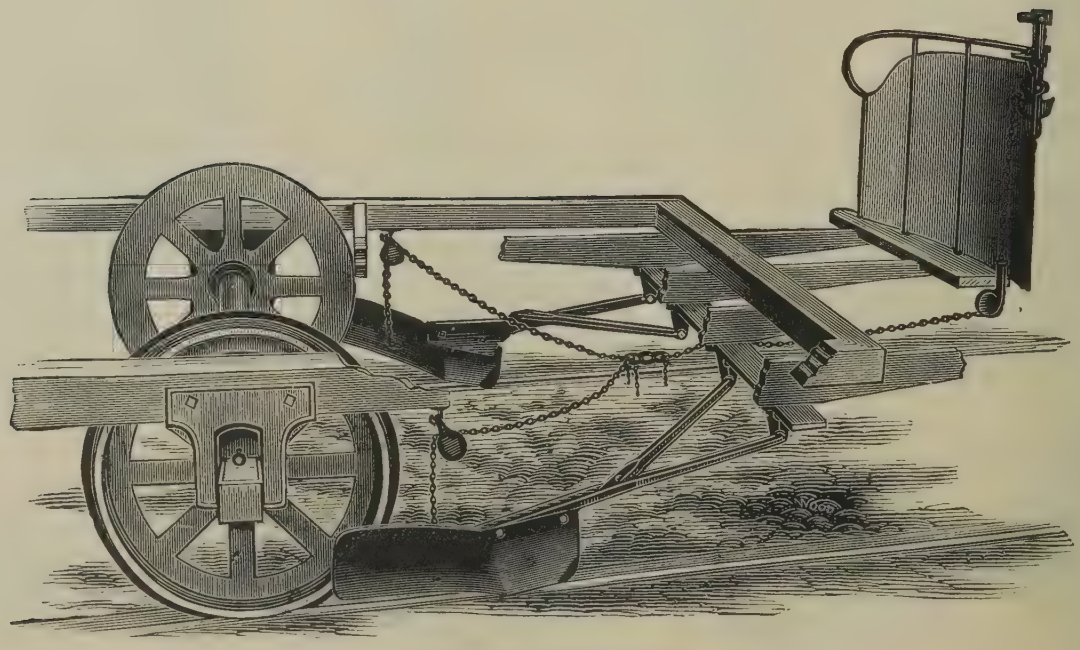


FIG. 43.—TRACK CLEANER.

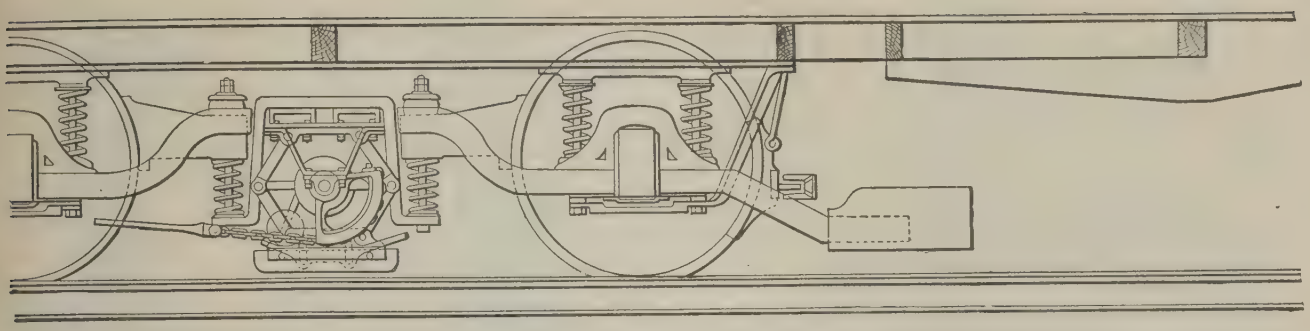


FIG. 45.—TRACK BRAKE FOR ELECTRIC CARS.

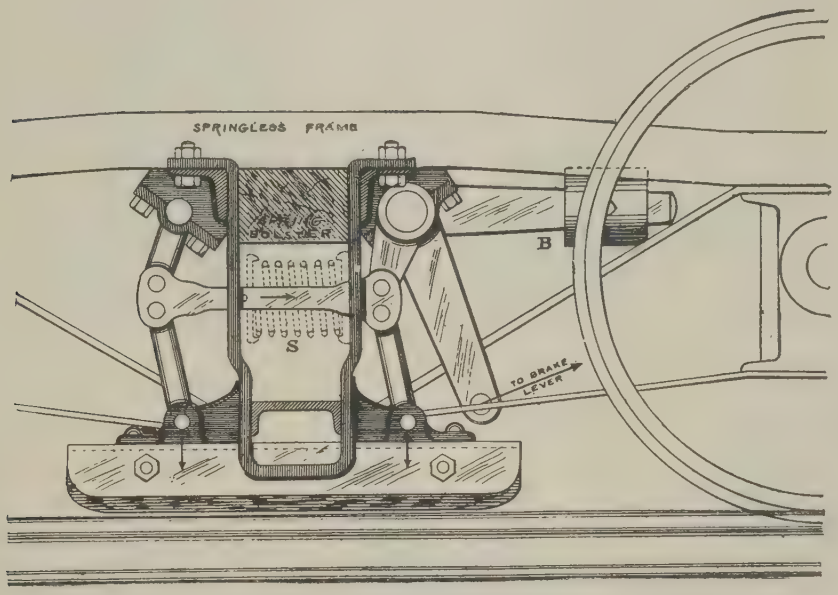


FIG. 46.—TRACK BRAKE

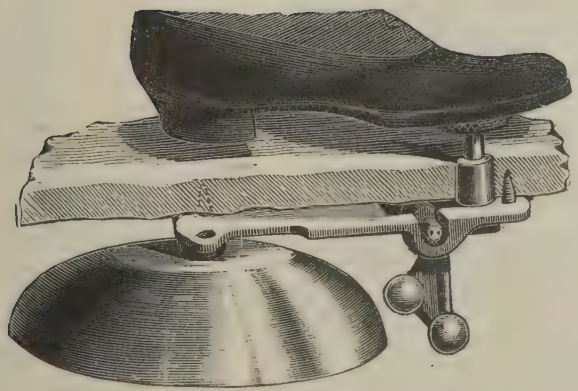


FIG. 47.—ROLLED STEEL PLATFORM GONG.

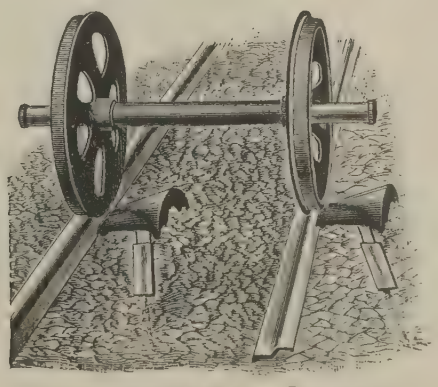


FIG. 48.—STREET CAR REPLACERS.

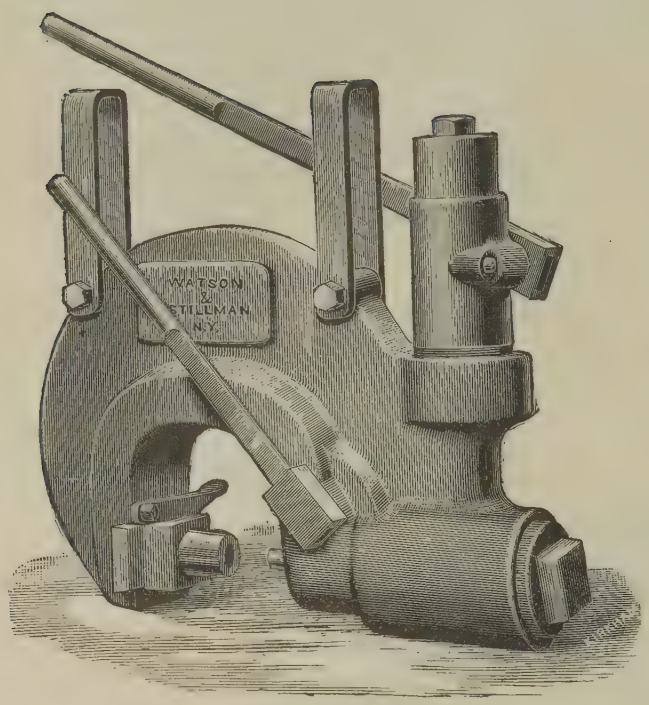


FIG. 49.—HYDRAULIC WEB PUNCH.

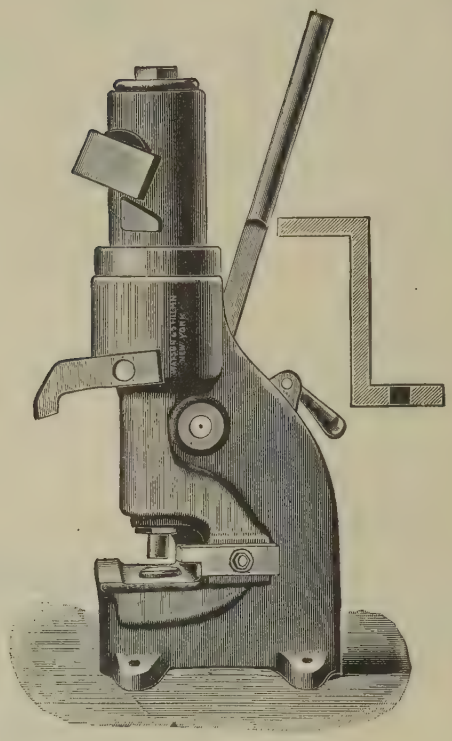


FIG. 50.—SPIKE SLOT PUNCH.

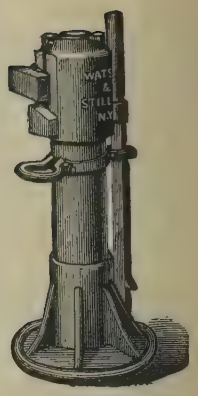


FIG. 51.—HYDRAULIC JACK.

FIG. 52.—CLAW HYDRAULIC JACK.

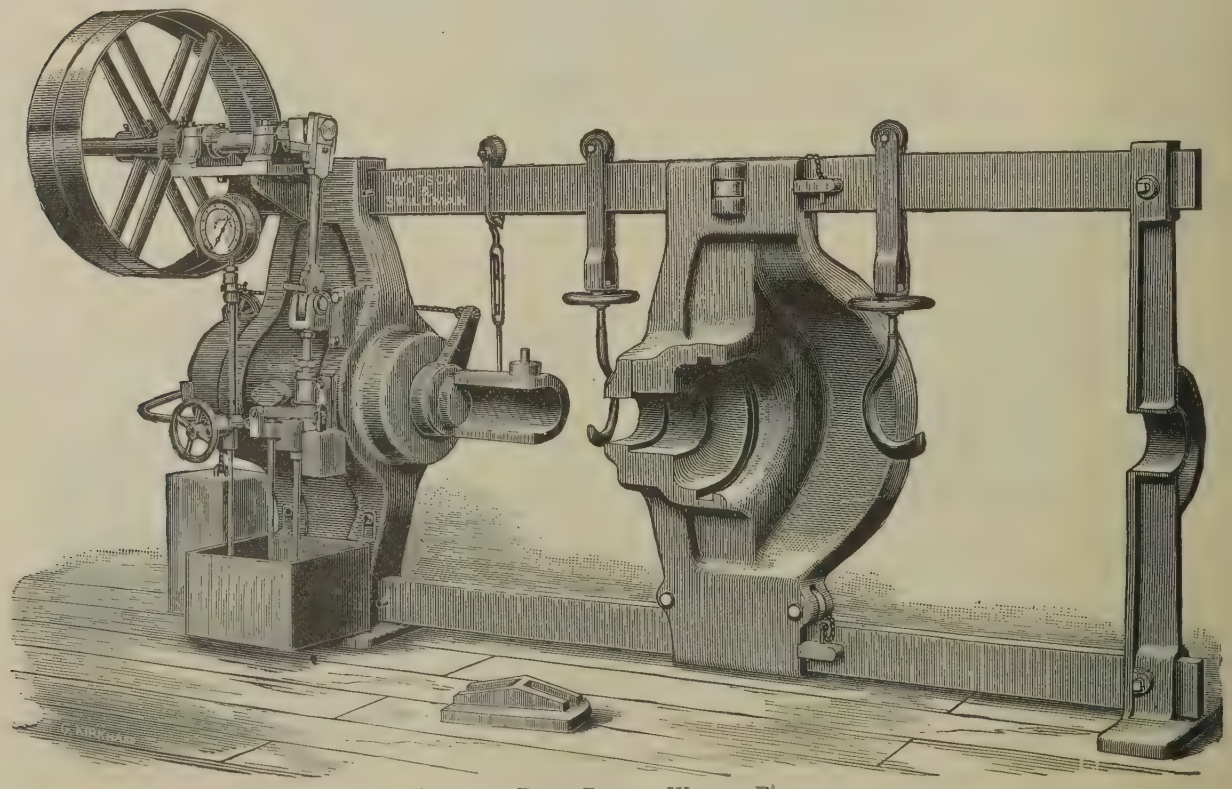


FIG. 53.—BELT POWER WHEEL PRESS.

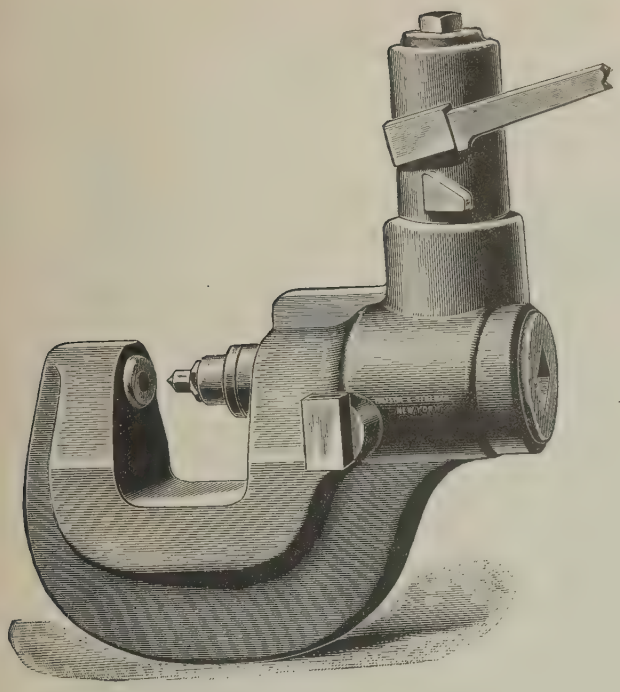


FIG. 54.—SLOT RAIL PUNCH.

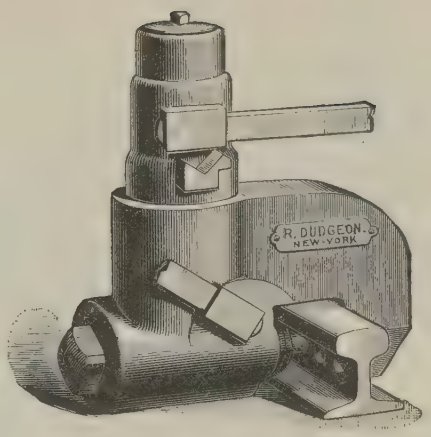


FIG. 59.—FISH PLATE PUNCH.

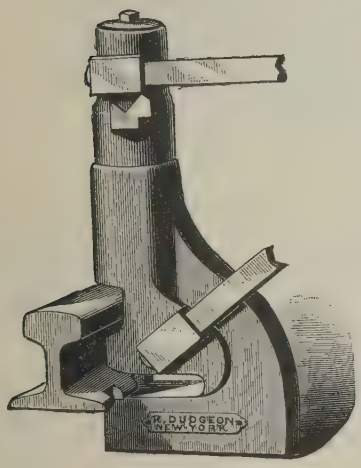


FIG. 55.—HYDRAULIC SPIKE PUNCH.

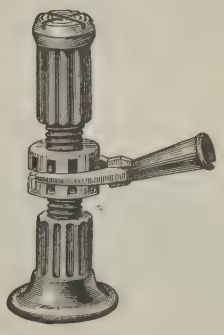


FIG. 57.—SCREW JACK.

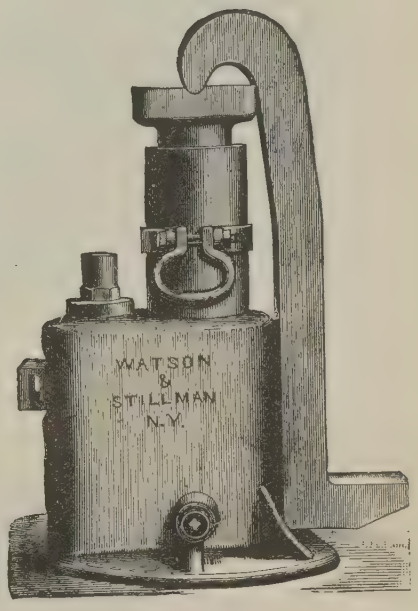


FIG. 60.—HORIZONTAL JACK.

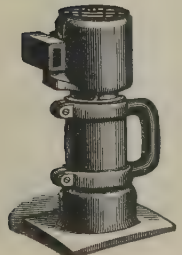


FIG. 56.—JOURNAL BOX JACK.

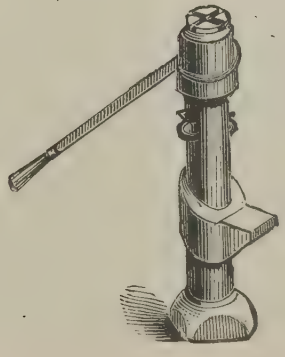


FIG. 58.—CLAW JACK.

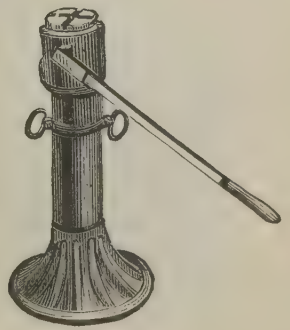


FIG. 61.—PLAIN JACK.

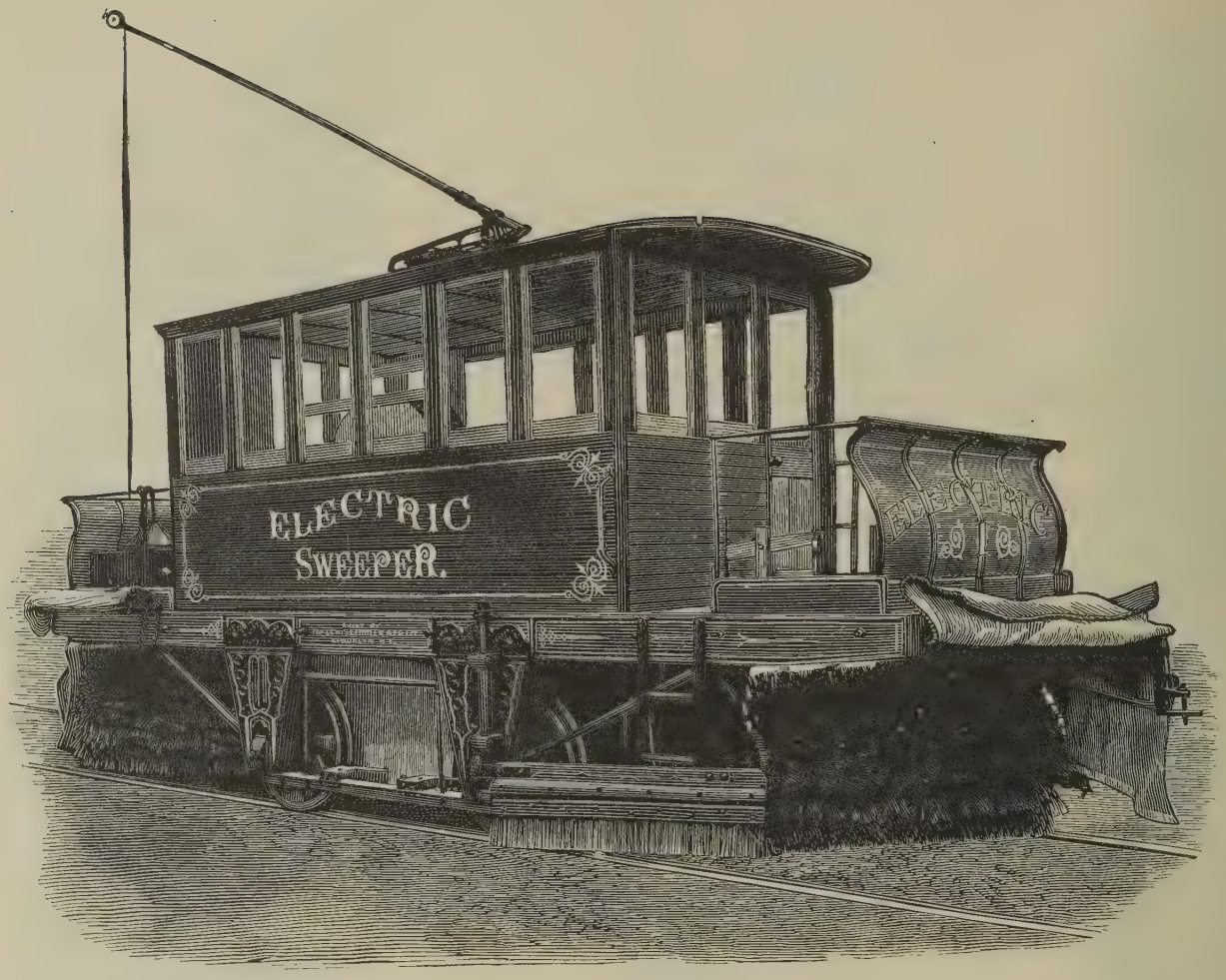


FIG. 62.—ELECTRIC SWEEPER.

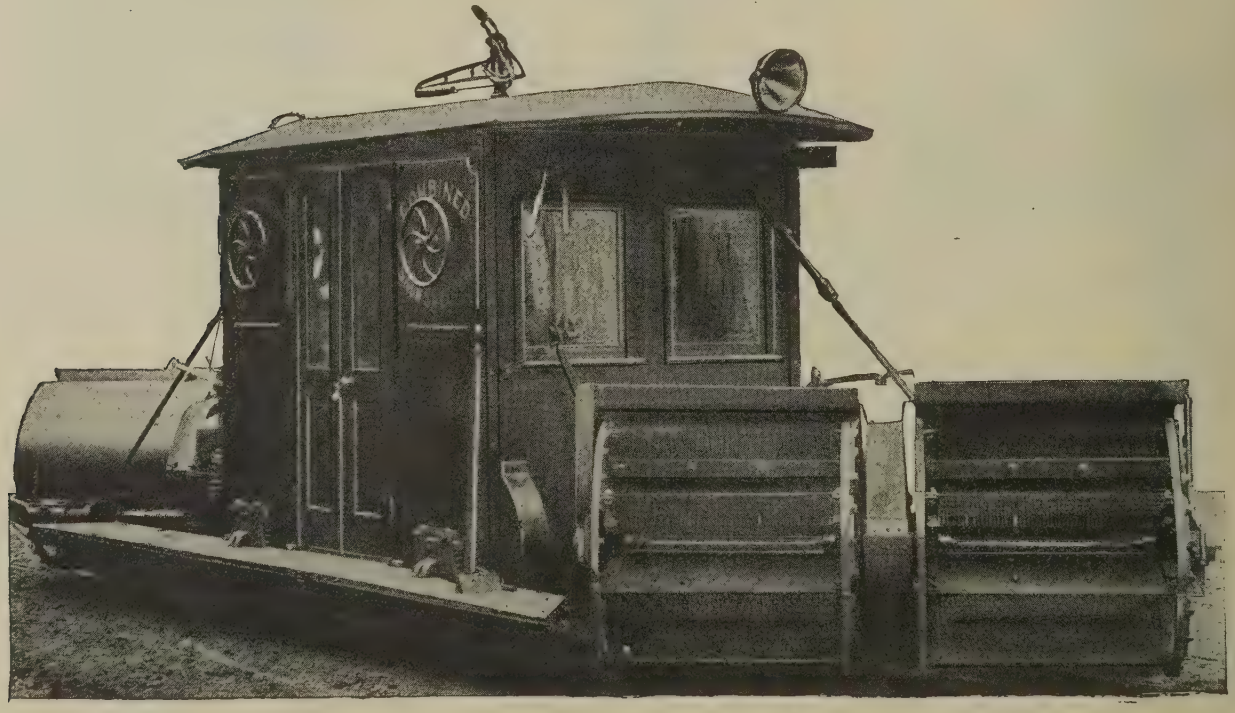


FIG. 63.—COMBINED ELECTRIC SNOW PLOW AND SWEEPER.

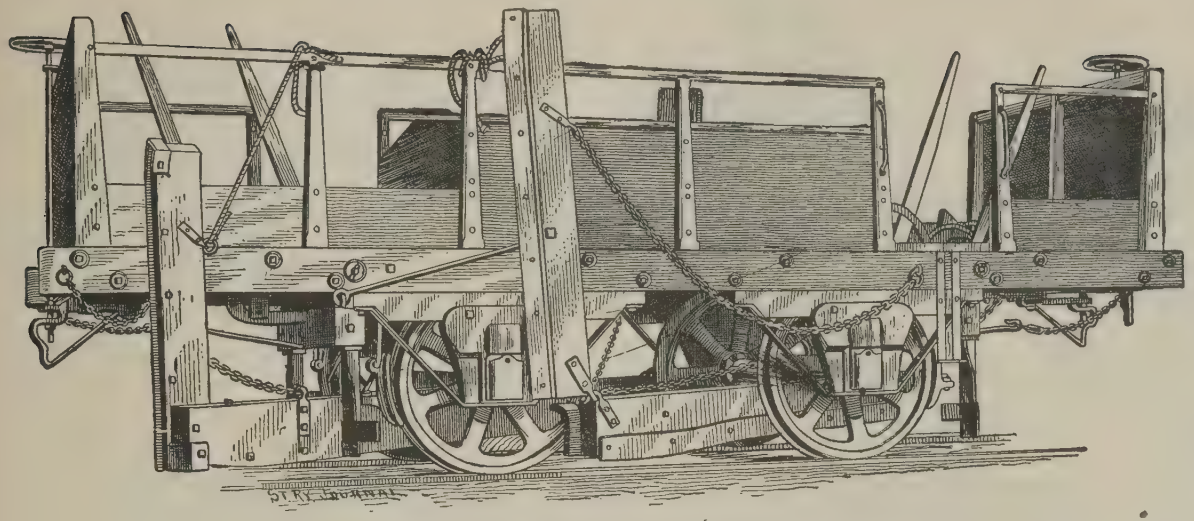


FIG. 64.—SNOW PLOW AND SCRAPER.

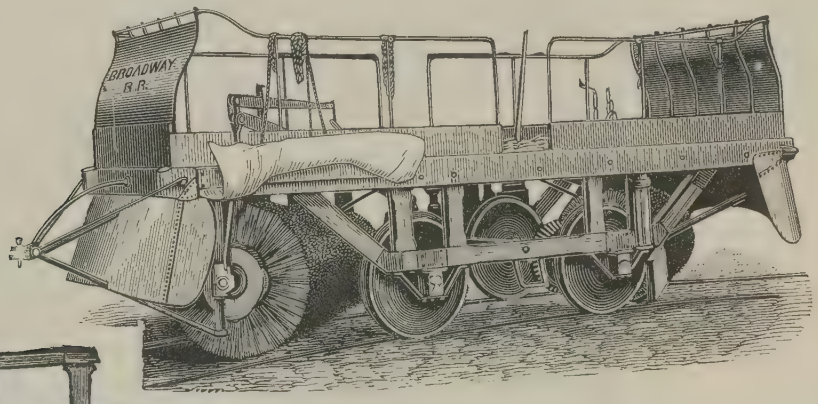


FIG. 64*a*.—HORSE TRACK SWEEPER.

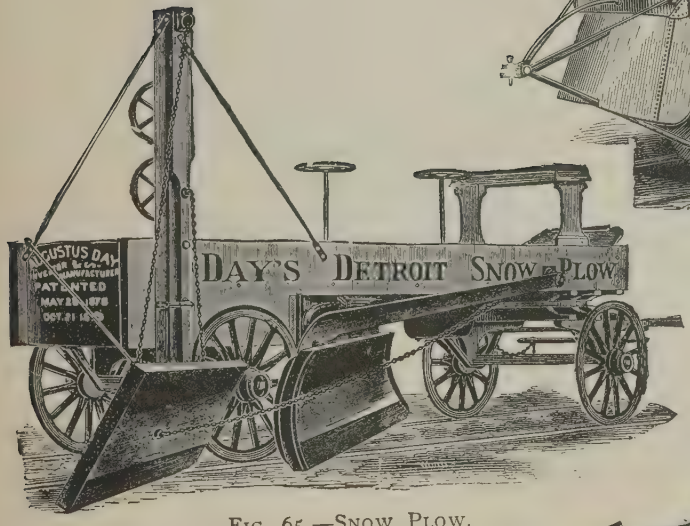


FIG. 65.—SNOW PLOW.

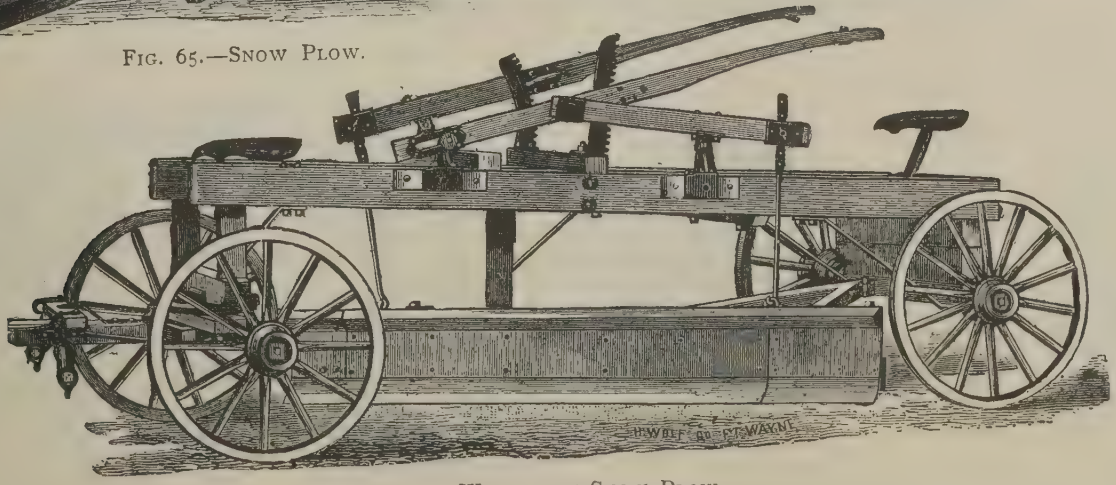


FIG. 66.—WALKAWAY SNOW PLOW.

FIG. 67.—WRECKING OR EMERGENCY WAGON.

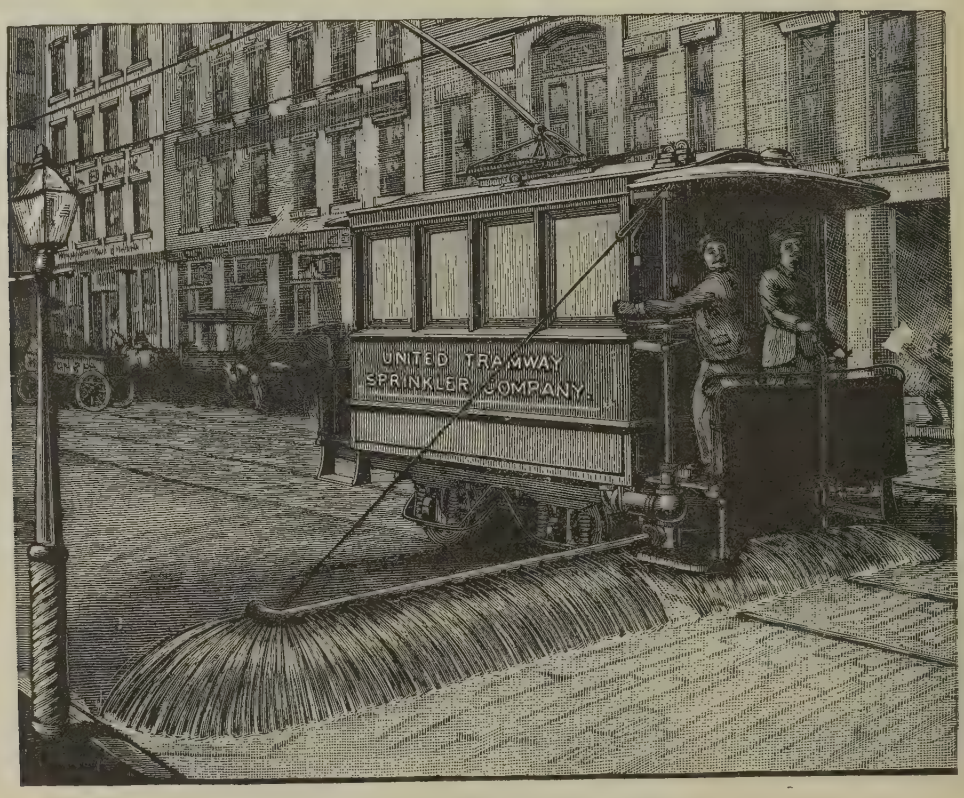


FIG. 68.—STREET RAILWAY SPRINKLER.

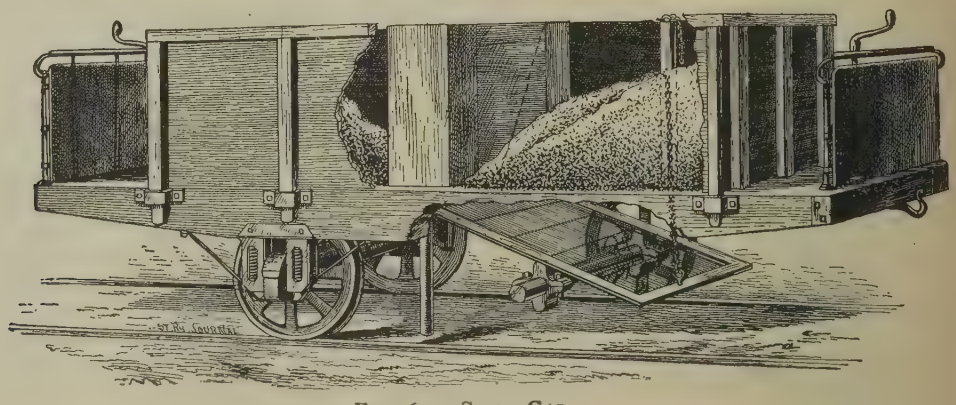


FIG. 69.—SAND CAR.

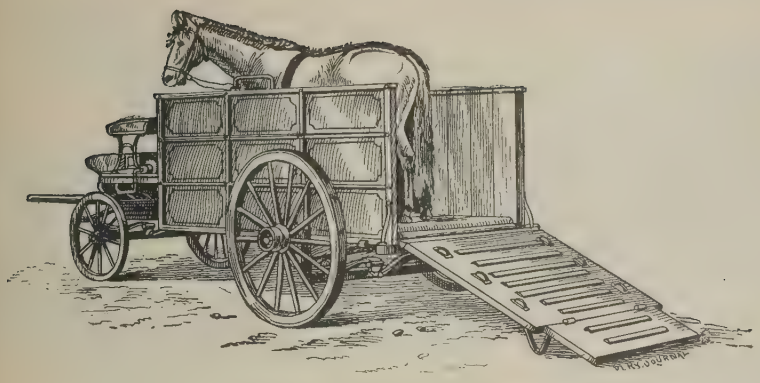


FIG. 70.—HORSE AMBULANCE.

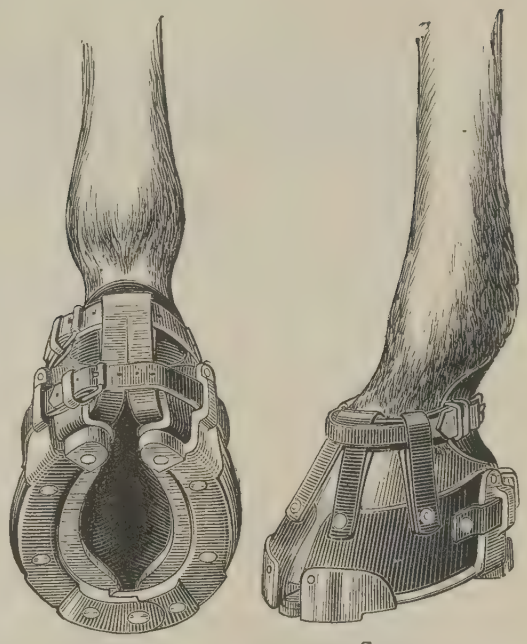


FIG. 74.—ADJUSTABLE SHOE.
(See page 143.)

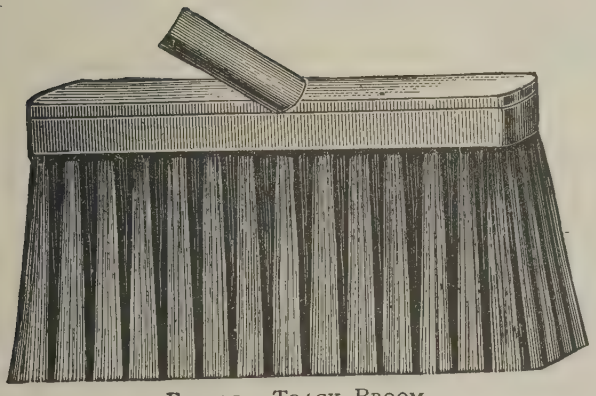


FIG. 71.—TRACK BROOM.

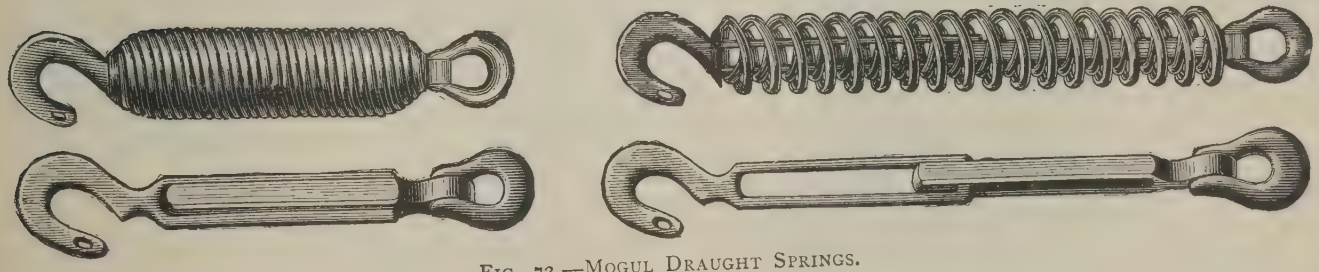


FIG. 72.—MOGUL DRAUGHT SPRINGS.

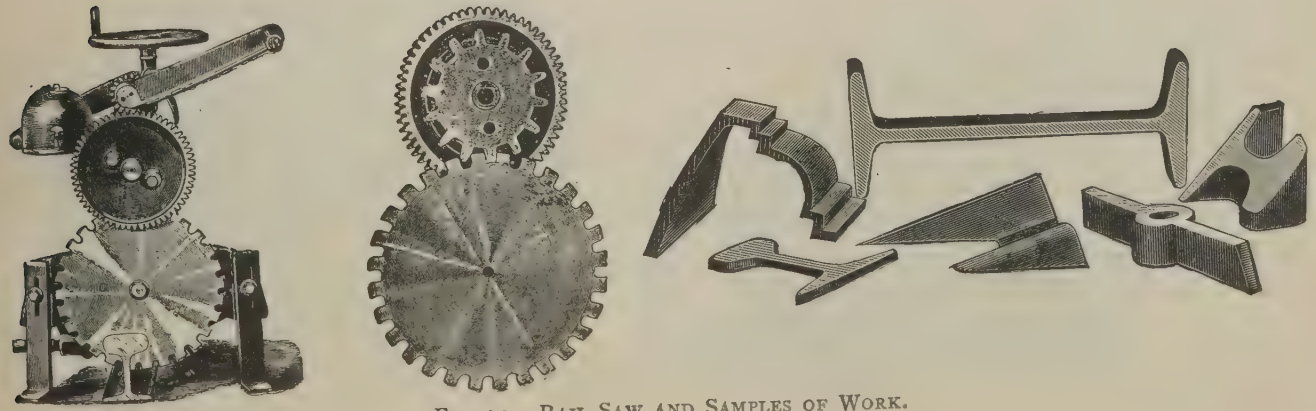


FIG. 73.—RAIL SAW AND SAMPLES OF WORK.

FIG. 75.—TRACK LIGHT.

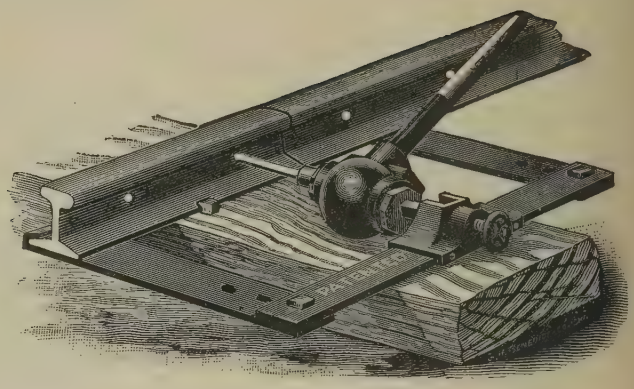


FIG. 77.—RATCHET DRILL.

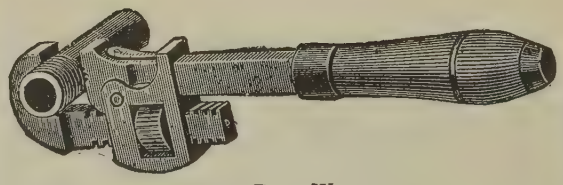


FIG. 78.—PIPE WRENCH.

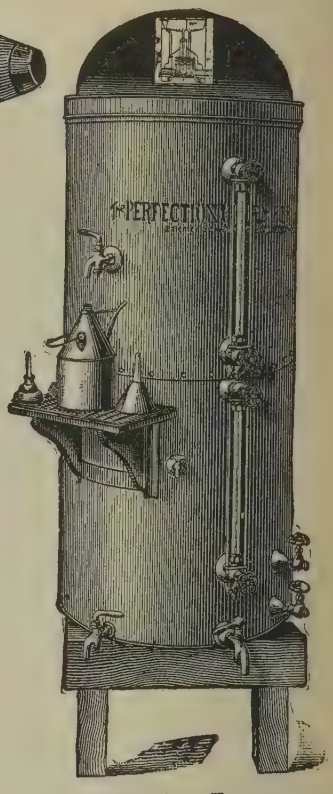


FIG. 79.—OIL FILTER.

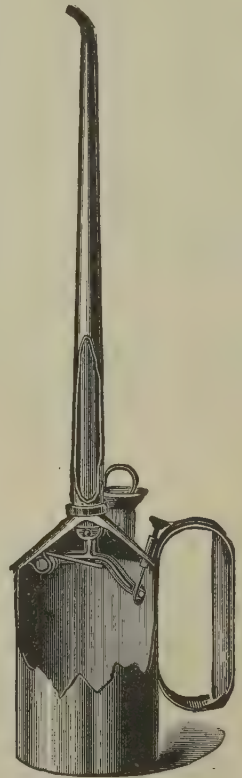


FIG. 80.—"PERFECTION" OIL CAN.

FIG. 76.—"PERFECTION" OIL CAN.

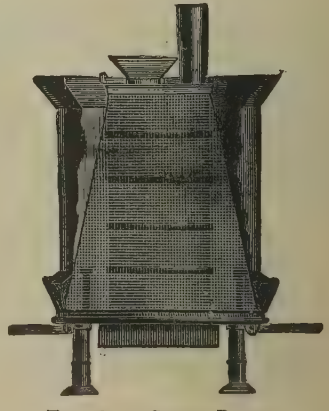


FIG. 81.—SAND DRIER.

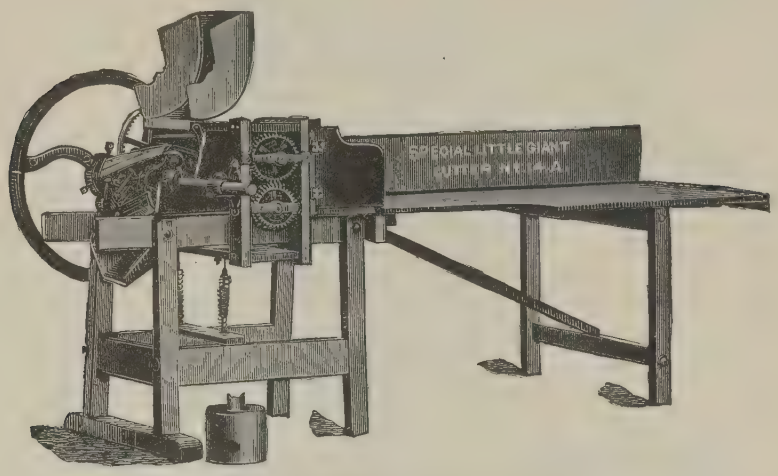


FIG. 82.—POWER HAY CUTTER.

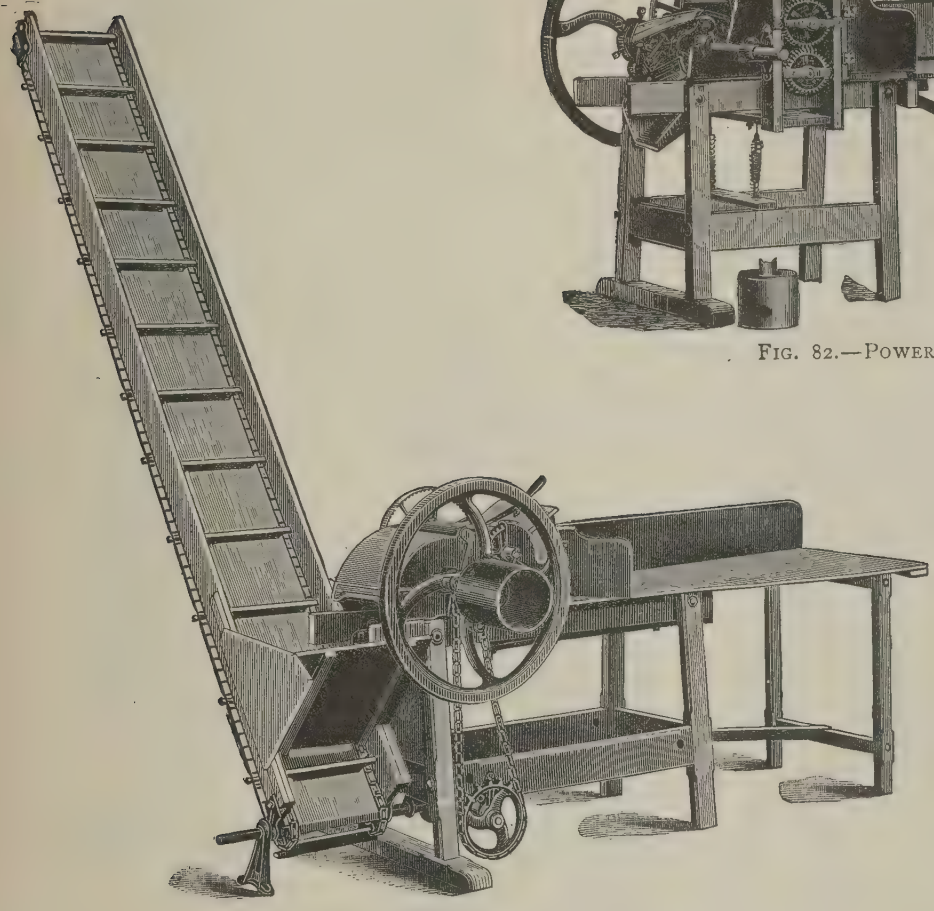


FIG. 83.—POWER HAY CUTTER WITH CONVEYOR.

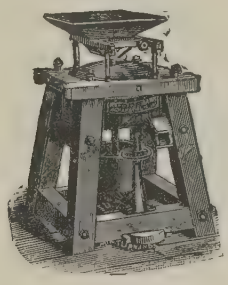


FIG. 85.—GRIST MILL.

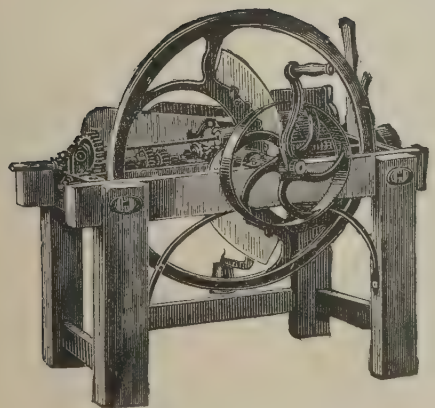


FIG. 84.—HAND HAY CUTTER.

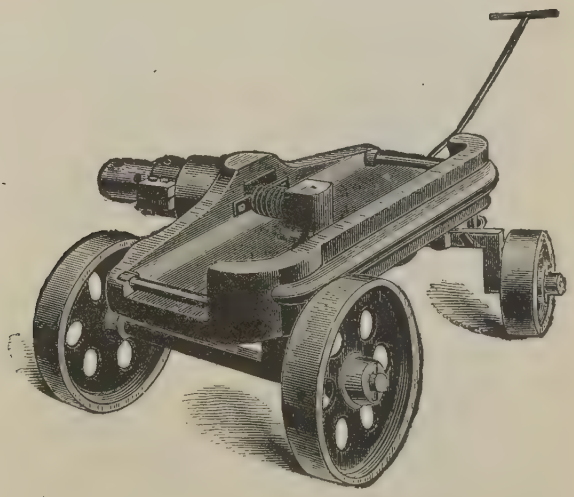


FIG. 86.—RAIL BENDING MACHINE.

FIG. 87.—GEARED DIFFERENTIAL PULLEY BLOCK.

FIG. 88.—DIRECT DIFFERENTIAL PULLEY BLOCK.

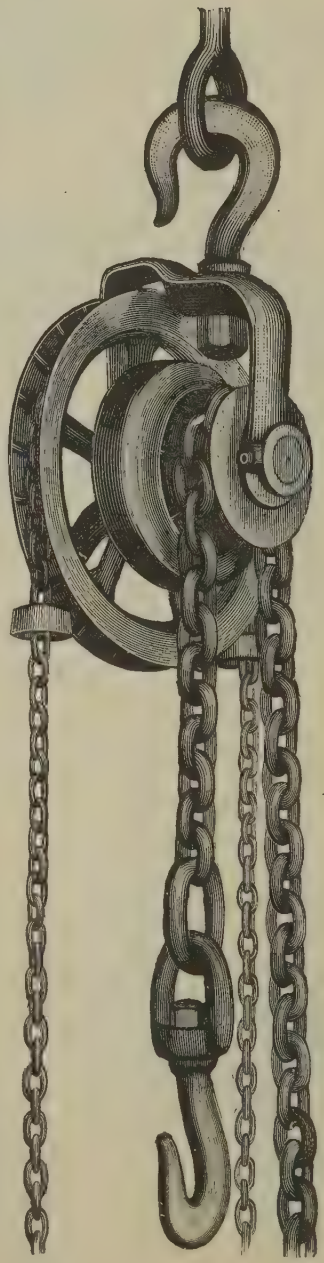


FIG. 89.—GYRATING HOIST.

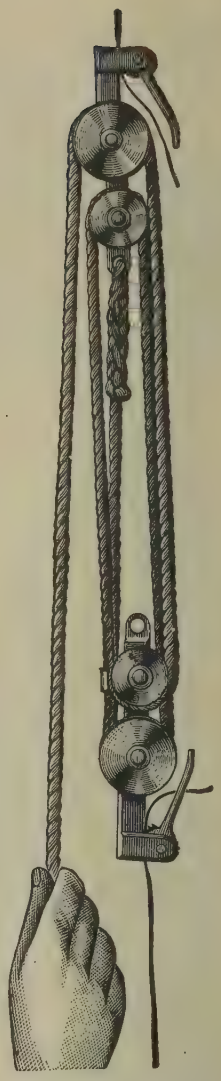


FIG. 90.—PULLEY BLOCK FOR STRETCHING WIRE.

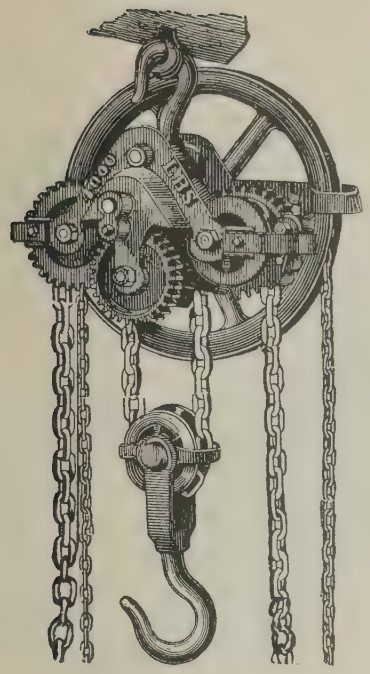


FIG. 91.—HAND HOIST.

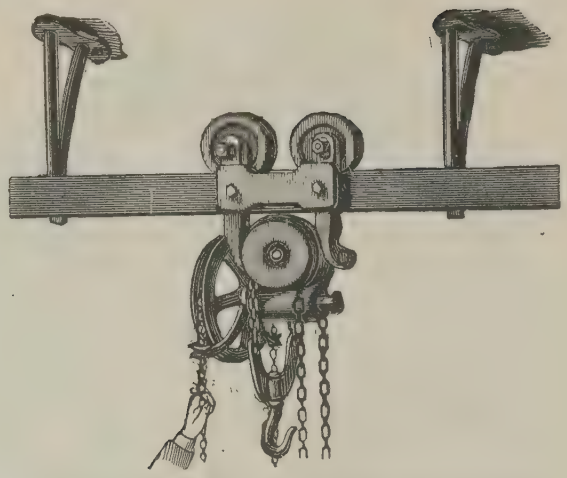


FIG. 94.—COMBINED HAND HOIST AND TROLLEY.

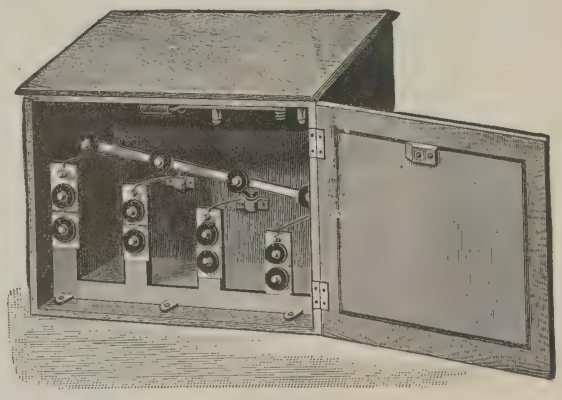


FIG. 95.—THE WASON LIGHTNING ARRESTER.
(Described on page 64.)

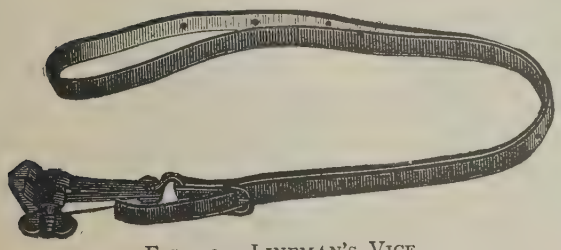


FIG. 92.—LINEMAN'S VICE.

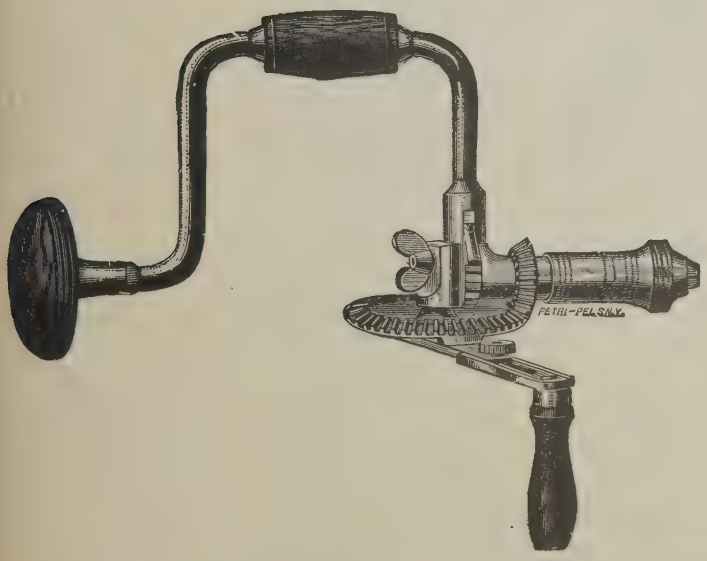


FIG. 93.—COMBINATION DRILL AND BIT BRACE.

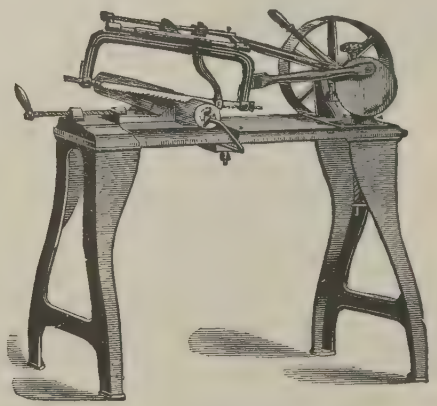


FIG. 96.—POWER HACK SAW.

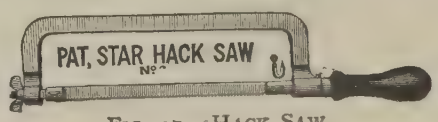


FIG. 97.—HACK SAW.

FIG. 98.—AUTOMATIC SWITCH.

FIG. 99.—AUTOMATIC SWITCH.

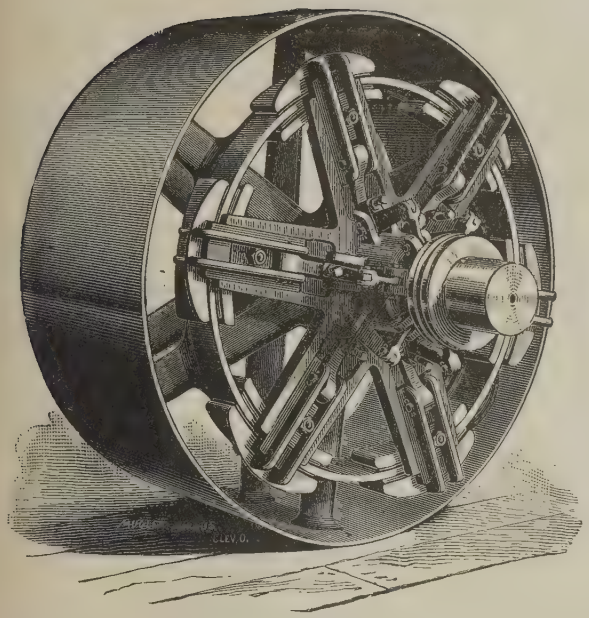


FIG. 100.—FRICTION PULLEY.

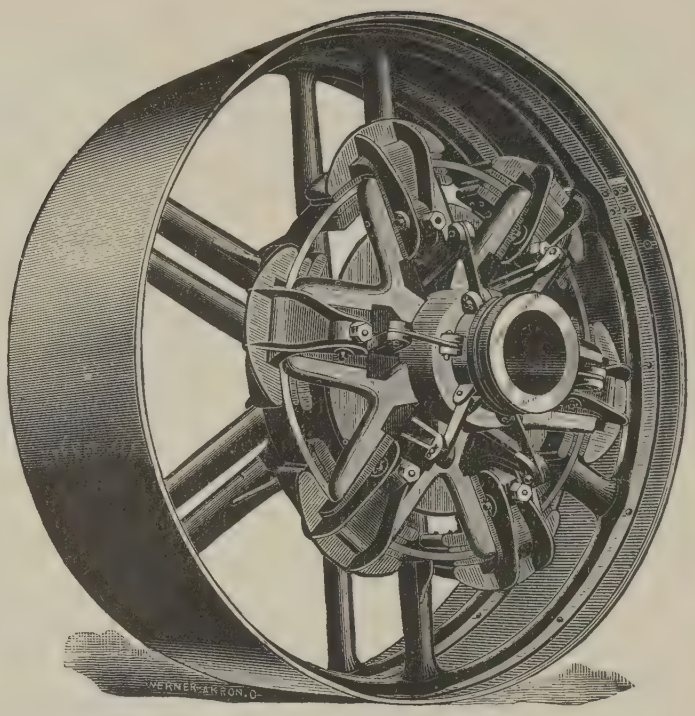


FIG. 101.—FRICTION PULLEY.

FIG. 102.—THREE PLY VENEER.

APPENDIX TO FIRST CHAPTER.

MOTORS.

The street car motor equipment which the Detroit Electrical Works early put in practical operation on a large number of street railways, and which consisted of placing one motor of ample capacity longitudinally under the car and coupling it by means of bevelled gear with both axles (p. 37), has been followed by a design that differs materially from the type formerly used by any system of motor equipment. From the accompanying engravings (Figs. 1 to 3), it will be noted that the new principle consists in coupling a single reduction motor to the axles, permiting the latter to be perfectly free to change their angular position without affecting the relation of the bevel gear and pinion, one to the other. The axles, although driven simultaneously from one armature shaft, are independent and free to adapt themselves to curves and uneven track, and even to run off the track without changing the mesh of the gears in the slightest particular.

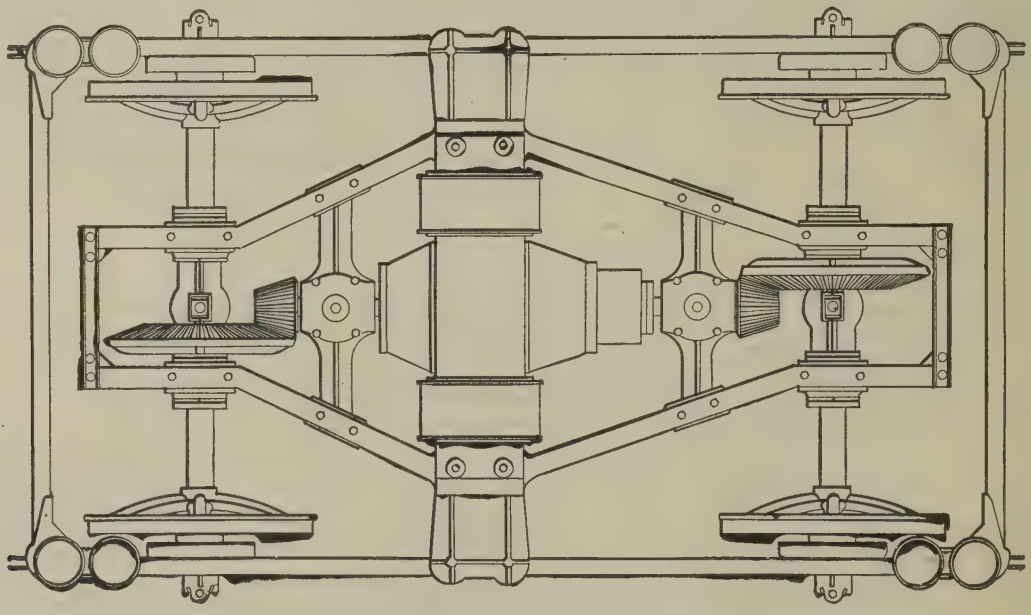


FIG. 1.—IMPROVED DETROIT MOTOR.

This flexibility, or universal movement, is accomplished by means of a new mechanical joint recently devised, which consists of a solid sphere turned on the axle at its middle, and a shell fitting snugly around it, after the fashion of the well known ball and socket joint. The shell is secured to the sphere or ball by two or more driving studs, with an annulus or loose nut over each. This nut is carried in an opening or slot in the shell, of the same width as the nut, but long enough in line with the axle to permit of the necessary travel of the shell on the ball in the motion accompanying any tendency for the car wheels to be thrown out of the same plane. The bevel gears for driving the axles are made in the form of a toothed rim, without centre or hub and are secured to the outside of the shell by bolts, but in such a manner as to receive their motion only through coil springs that are always under compression. This resiliency of the larger gears fills the three-fold purpose of (*a*) lessening the wear of the teeth ; (*b*) relieving the teeth from shocks in starting the car or striking obstacles ; and (*c*) of accommodating any unequal wear of one pair of wheels over the other in the same truck, without subjecting the armature shaft

to any strain other than its normal work of rotation. The gears and pinions are of the "shrouded" type, each pair being of sufficiently ample proportions and strength to transmit the full power of the motor should any accident happen to one pair of wheels or their axles.

The shell surrounding the ball on the axle, and

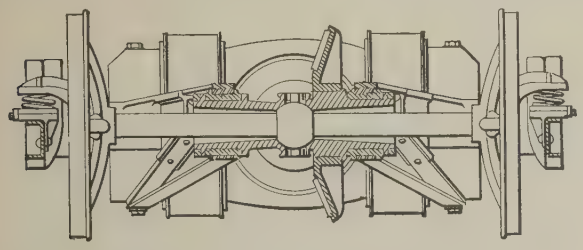


FIG. 2.—FLEXIBLE GEAR SHAFT—DETROIT MOTOR.

through which the motion to the axle is imparted by means of the stud and loose nut, is journaled at each end, through which the axle passes, in the frame supporting the motor and connecting the axles together; the novelty being here introduced of permanently fixing the *driving* shaft, or shell in this case, and permitting the *driven* shaft, or axle, to change its relative position at will. All parts of this new joint are made of steel to secure requisite strength with minimum weight and size. The only wearing surfaces are the journals of the shell in the frame and the loose nut on the driving studs, the shell not moving on the ball except to compensate for irregularities in track. The journals of the shell are, therefore, made very large; and, as no pressure of consequence is brought on them, the wear, it is expected, will be very slight. The stud nuts are made of phosphor bronze, and can be readily slipped off from outside the shell when worn, and replaced by new ones in a few moments' time at a trifling expense.

The "diamond" truck—so called from the figure formed by the truss rods—has been adopted for this motor which is carried in the frame, as shown in the cuts accompanying, but the weight is carried on the outside truck through coil springs placed in caps on top and bottom, so arranged as to permit the requisite weight to be received by the springs when the motor is placed, and securely fastened thereafter.

The motor proper is of a double magnet type, used extensively heretofore by this company in all of its standard double reduction equipments. The size illustrated is of capacity sufficient, it is claimed, to develop forty mechanical H. P. continuously for eighteen hours without undue heating of wires or commutator, but it may be safely worked at fifty H. P. for short periods of time. The armature speed is 240 turns per minute, which not only allows of a very low ratio of gearing (three to one ordinarily), but also permits of a very slow car travel where conditions on city lines require it. The maximum speed attained with the use of the usual controlling arrangement for this motor, is twenty-five miles per hour.

The fields are forged from the highest grade of scrap, and all the wire used on the armature and field coils is carefully insulated at the company's factory. The armature itself is wound by a

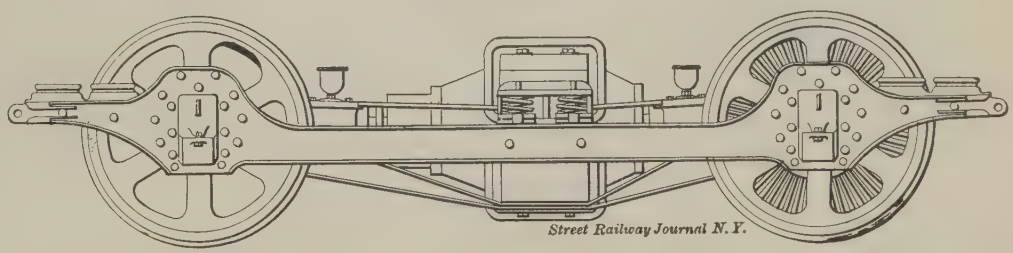


FIG. 3.—DIAMOND TRUCK—DETROIT MOTOR.

method patented and owned by the company. The removal of the armature from the motor is effected at the top by removing the upper field magnet. The electrical efficiency of the motor is claimed to be ninety-one per cent., and, as the gearing is simple in arrangement and all bearings are large, the resulting mechanical efficiency of the whole machine is said to be not less than eighty per cent.

The weight of the forty H. P. equipment illustrated is, approximately, 6,000 lbs. exclusive of the

outside truck frame, but including wheels and axles. The company furnish these latter with the motor, and adapt the machine to any make of car truck desired by the street railway companies.

The latest types of Eickemeyer-Field electric motor trucks for street railway cars are shown in Figs. 4 and 6. The first has a six foot wheel base, and is designed for a sixteen foot or single truck car, the second has a four foot eight inch wheel base, and is designed for a double truck car. As will be seen, the apparatus differs in many important particulars from any heretofore described, and in both trucks consists essentially of a gearless motor mounted in a frame of special design, and arranged to drive both axles by means of parallel rods; thus, all the wheels move in unison, which wholly overcomes the tendency to slip on wet rails or curves.

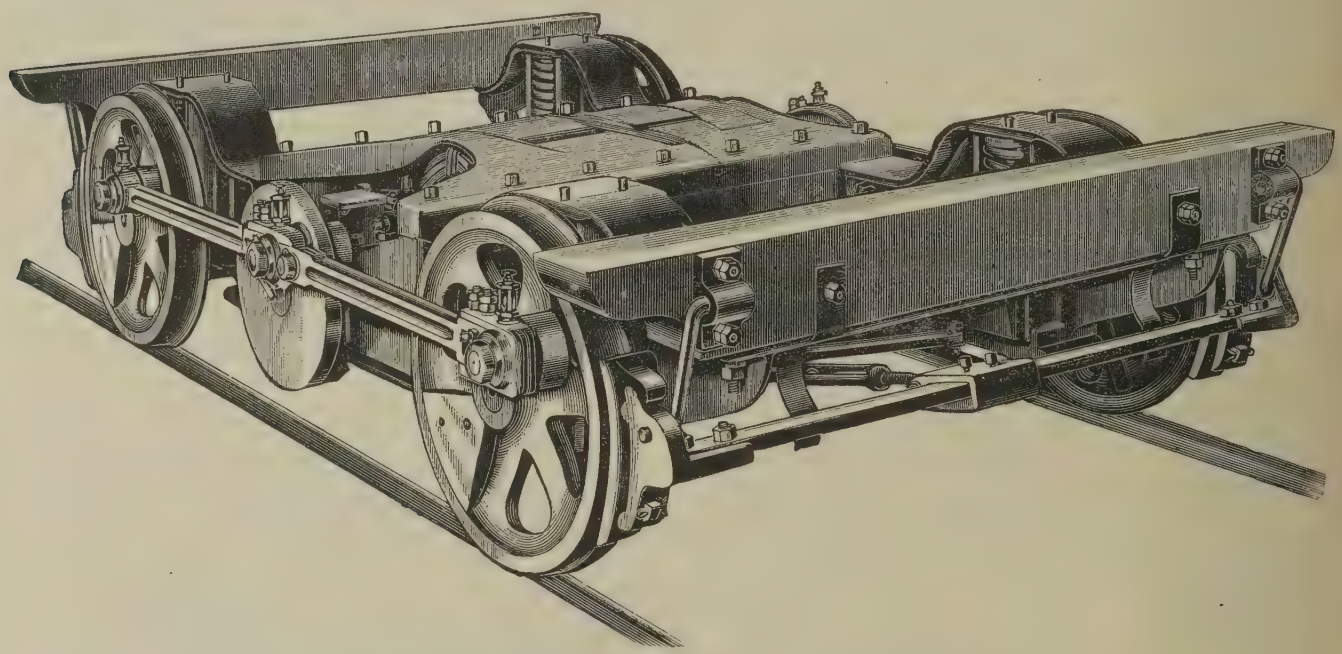


FIG. 4.—EICKEMEYER-FIELD ELECTRIC MOTOR TRUCK.

The motor is of the iron clad type; the cast steel casing which entirely surrounds the field coils and protects them from accidental injury also acts as a part of the magnetic circuit. The field coils are not mounted on pole pieces, but surround the armature, making the length of magnetic circuit as short as possible and utilizing all the lines of magnetic force. The field is commutated for speed regulation, and when the coils are in parallel has a resistance of less than one-half ohm. The armature has a resistance of three-quarters of an ohm and is built up of wrought iron discs, and wound with coils of No. 9 B. & S. wire, so arranged that the separate armature coils do not cross each other, and any one can be removed. This arrangement secures perfect electrical and mechanical balance in all positions of the armature; each coil is of the same resistance, and every convolution in the same relative position with reference to its opposite convolution.

The motor is mounted in the frame in such a manner as to permit of easy inspection or access to any part, a removal of but four bolts allowing the motor to be run from under the car body. The thirty-five H. P. motor, such as is used on the trucks shown has a speed of 150 revolutions per minute when the car is running at twelve miles per hour.

The frame supporting the motor is a single, nearly square casting, and is entirely closed underneath, so that no mud or moisture from the street can reach the electrical apparatus. It is spring supported on the axles, so that the motor is absolutely rigid in the direction of travel, while cushioned vertically. To allow free movement of motor and car in every direction, the connecting

rods are jointed and provided with swivel boxes at their extremities, so that, no matter what track irregularities are encountered, there is no consequent binding of parts or undue friction. The weight of the complete thirty-five H. P. motor truck, including wheels, axles and fittings is 9,000 lbs., and its total efficiency of operation is said to be eighty per cent.

Owing to the location of the motor between the two axles where ample space is available, the car wheels with this system are only twenty-six inches in diameter, the lowest part of the motor frame being four and a half inches above the ground. This not only makes the car easy of access for passengers, but also gives a low centre of gravity for the entire car and truck, with corresponding decrease of any oscillating motion.

Among the special advantages claimed by the manufacturers and proved by extended operations during the past year, are (*a*) that owing to the fact that no dead weight is carried on the axles the detrimental effect to motor and rails from irregularities of track is small, and the cars can be operated on rails of medium weight such as are found on existing horse car lines, thus avoiding the expensive re-equipment with heavy rails found necessary in the introduction of many other systems ; (*b*) that by the method of connection between the armature shaft and axles the loss of power by friction of gears is reduced, and the mechanism made absolutely noiseless; while at the same time (*c*) the motor does not surround the axles, and all parts are easy of access, and can easily be removed if necessary. Fig. 5 shows a sixteen foot Eickemeyer-Field car in operation, and Fig. 7 gives a view of a thirty-three foot car with swivel trucks.

Fig. 5.—Sixteen Foot Cars Equipped with Eickemeyer-Field Motors.

The Wightman electric railway motor shown in Figs. 8 and 9 is of the single reduction, iron-clad type, the field coils being entirely protected by the magnet frame. There are four poles, excited by two sets of field windings, each winding consisting of three separate coils. The armature is of the Gramme ring type.

The commutator is cross connected, so that only two brushes are required, these being placed on the

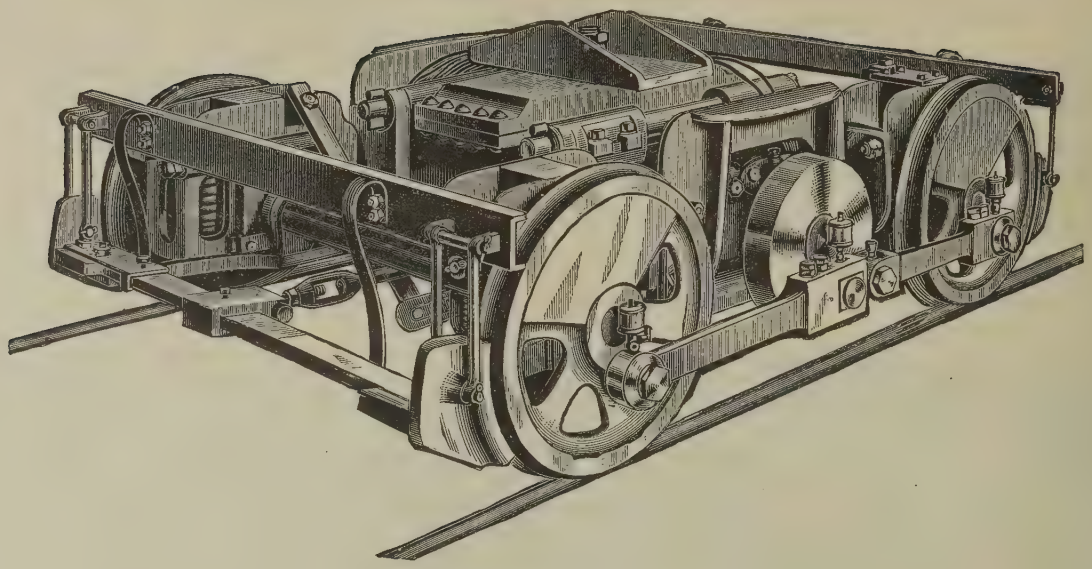


FIG. 6.—EICKEMEYER-FIELD BOGIE TRUCK FOR LONG CARS.

FIG. 7.—EIGHT WHEEL CAR EQUIPPED WITH EICKEMEYER-FIELD MOTORS.

top of the commutator ninety degrees distant from each other. The crossing cables are formed into a flat disc which is firmly bolted to the head of the commutator, reducing the possibility of breakage from vibration or other cause. The commutator can be readily removed from the armature shaft, if necessary, since each bar is fastened to its own lead wire without screws, and in such a way that the two can be readily detached. The armature bearings are self oiling and dust proof; and are mounted on a substantial frame forming part of the field magnet casting.

Fig. 9 shows clearly the style of casing used with the motor, which, while practically dust and water proof, permits of ample ventilation. The casing is made of sheet steel firmly riveted to the motor frame, and so arranged as not to interfere with easy access to the motor.

The gear case is of malleable iron in three parts, easy to attach and take off, and at the same time so fastened together that the parts cannot work loose.

The motor is sleeved upon the car axle at one end and flexibly supported at the other end by

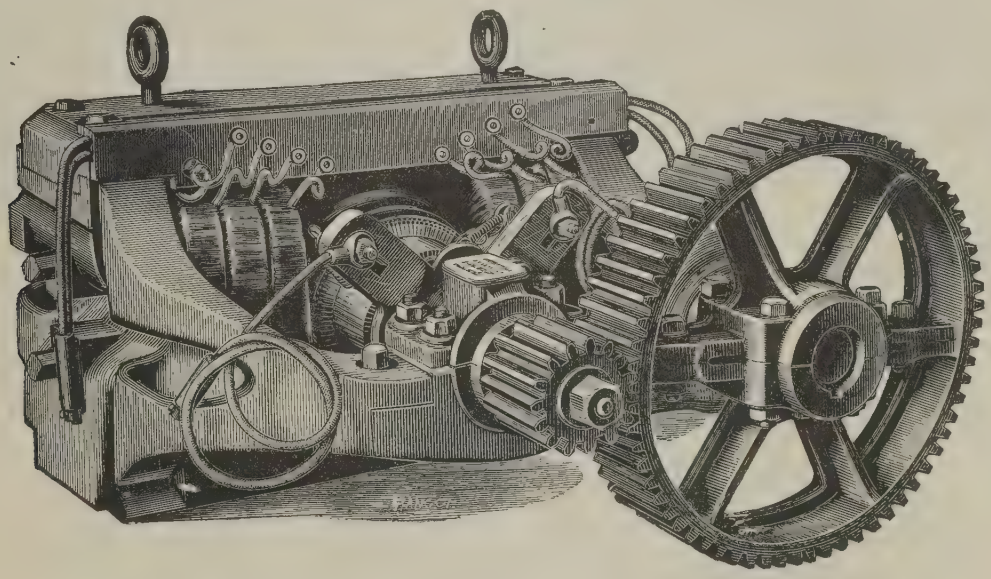


FIG. 8.—WIGHTMAN MOTOR.

The armature pinion has fifteen teeth and a diameter of five inches, the reduction in gearing being 4.4 to 1. This, with a car speed of ten miles per hour, gives 480 revolutions of the armature shaft per minute.

A conspicuous feature of the motor arrangement is the ready access to every part. The top field pole is hinged at one end, so that by the removal of two bolts, which makes it possible to lift off this pole, one set of field coils can be removed without disturbing the other or the armature. The resistance of the armature is .75 ohm, and that of the main field coils .15 ohm, and the commercial efficiency of the motor is said to be as high as eighty-seven per cent.

the use of a flat steel spring carried on the cross bar of the truck as shown. The weight of each motor, with casing and gears complete, is 2,200 lbs.

The controlling switch has the speed controlling handle and the reversing handle combined in one, and regulation is obtained without the use of any external resistance above a car speed of three or four miles per hour. There are five speed contacts possible for each direction of operation. The tendency of the current to arc in the regulating device on breaking contacts is prevented by the agency of a magnet fixed on the back of the switch-base. The poles of this magnet come directly opposite the space between the contacts, and it

blows out any arc formed, by the well known action of a magnet pole upon an electric current. The rheostat is three inches in diameter by eight-

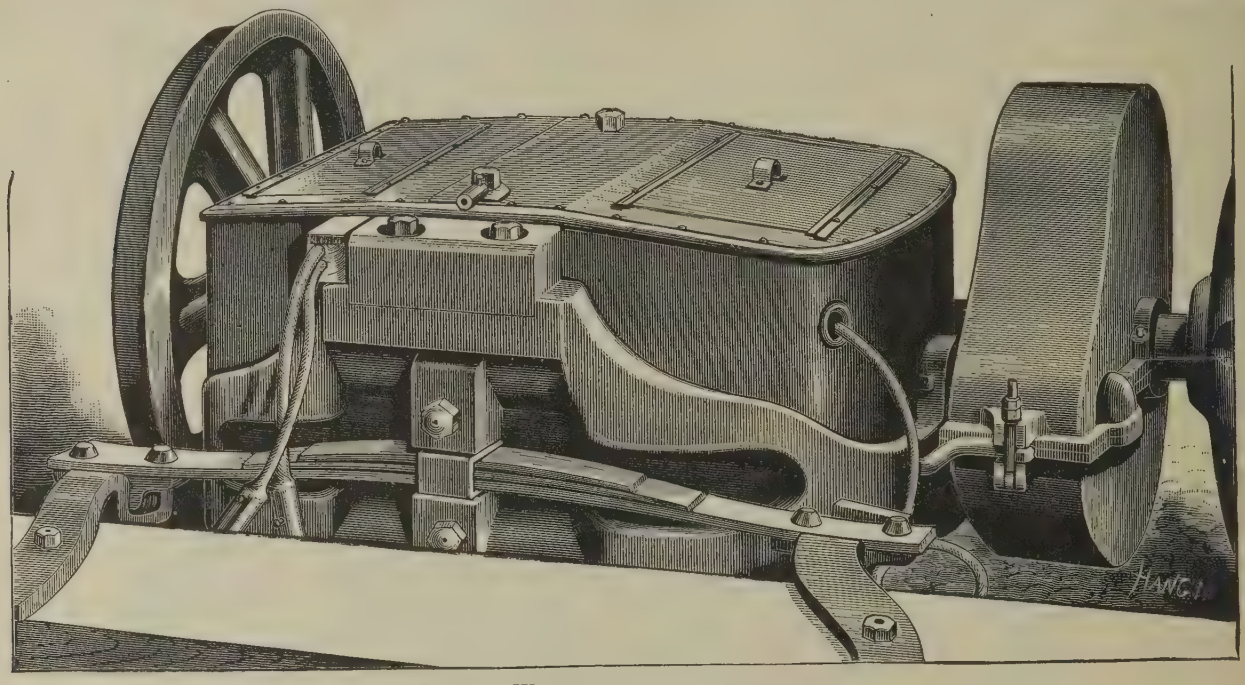


Fig. 9.—Wightman Motor Encased.

een inches long, is fire proof, and has a resistance of twelve ohms. The special claims made for the motor are high economy with the varying speeds and loads met in street railway practice, and durability secured by having a motor of ample capacity for the work required.

The wide demand for an electric motor adapted to a narrow gauge car induced the Thomson-Houston Electric Co., during the latter half of 1891, to manufacture a machine for this purpose, and the success of the motor has been so great that it has been employed on a number of standard gauge roads.

The electrical parts of this motor are so carefully protected from mechanical injury, snow and water,

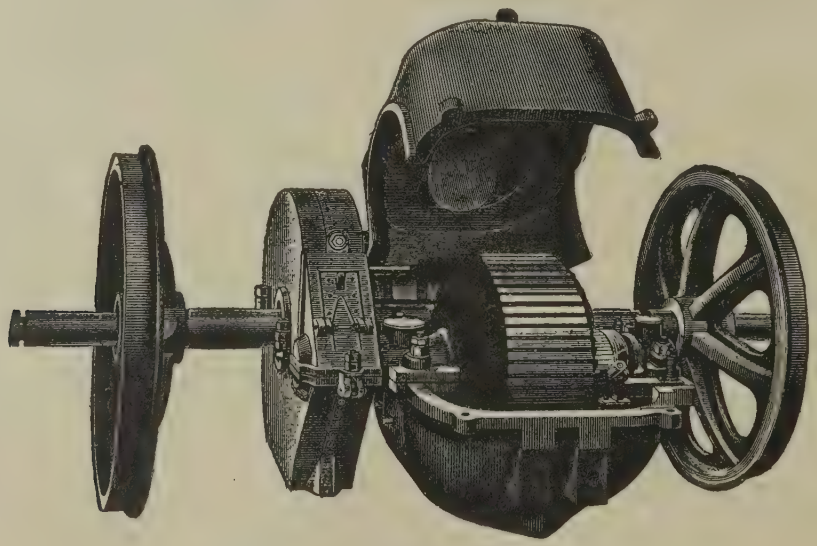


Fig. 10.—Waterproof Motor.

that the machine has taken its name from this feature, and is called W. P., or waterproof.

The motor frame (Fig. 10) consists of two steel castings clamped together by bolts at the front

and back, the axle brasses being held together between the two parts. The lower casting is shaped somewhat like a boat, rounding up from a plow shaped bottom which will throw aside stones or other obstructions which may be encountered on the track. The upper half meets the lower except upon the armature bearings where holes are left for access to bearings and commutator for ventilation. Only one field spool is used, and this surrounds the armature and upper pole piece, and is itself completely covered by the frame.

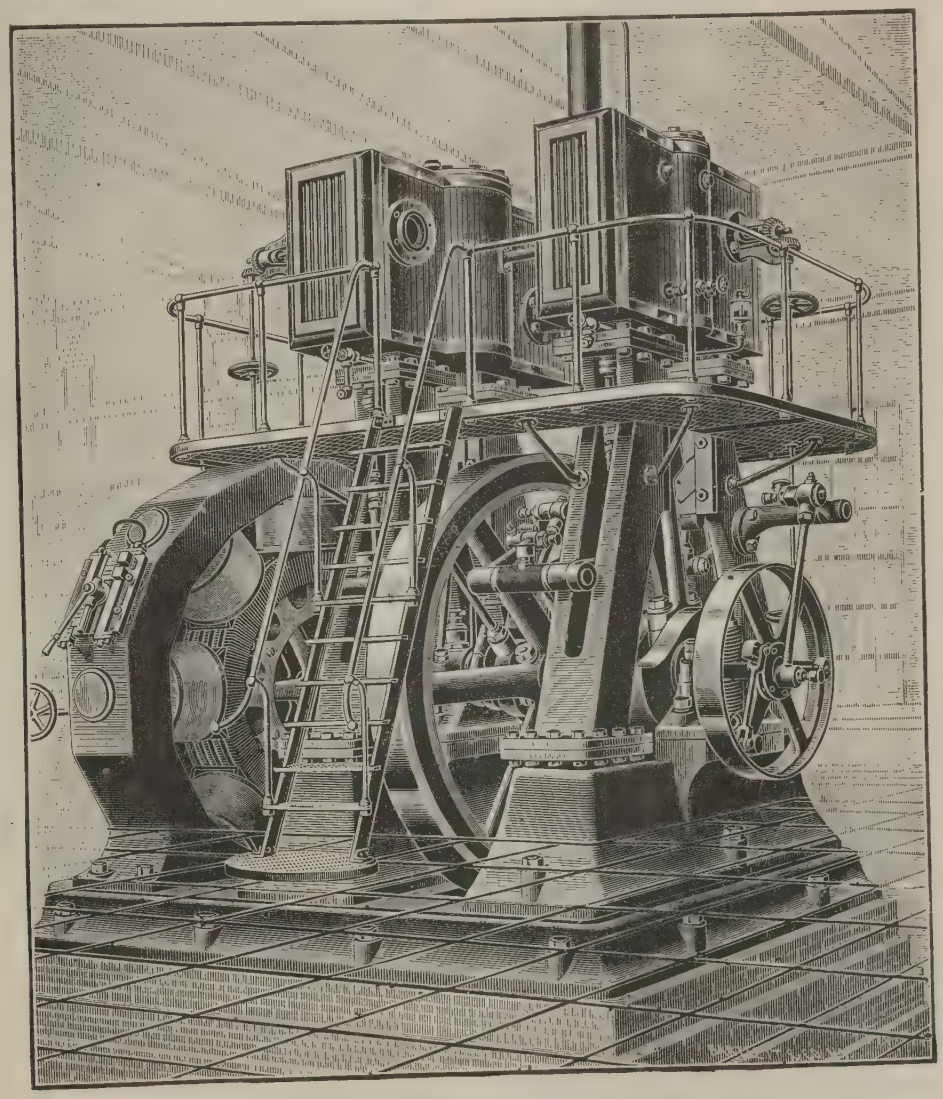


FIG. 11.—DIRECT COUPLED VERTICAL ENGINE AND MULTIPOLAR GENERATOR.

A feature of this machine is the fact that it is so proportioned that at its normal load the solenoidal pull of the field is sufficient to lift the armature and relieve the bearings of its weight. There will, therefore, under ordinary conditions, be no tendency to undue heating at this point. The parts of the frame being hinged together at the axle end, the armature can be readily removed. The motor being completely enclosed below, can be run in water up to the axle without injury.

Not only is the motor, as a whole, iron clad, but the armature is also iron clad. The core is a ring with projecting teeth between which the coils are wound and held firmly in place by wooden wedges. No binding wire is used, and to replace the coil it is only necessary to draw out a wedge, and the coil can be rewound without disturbing the rest of the

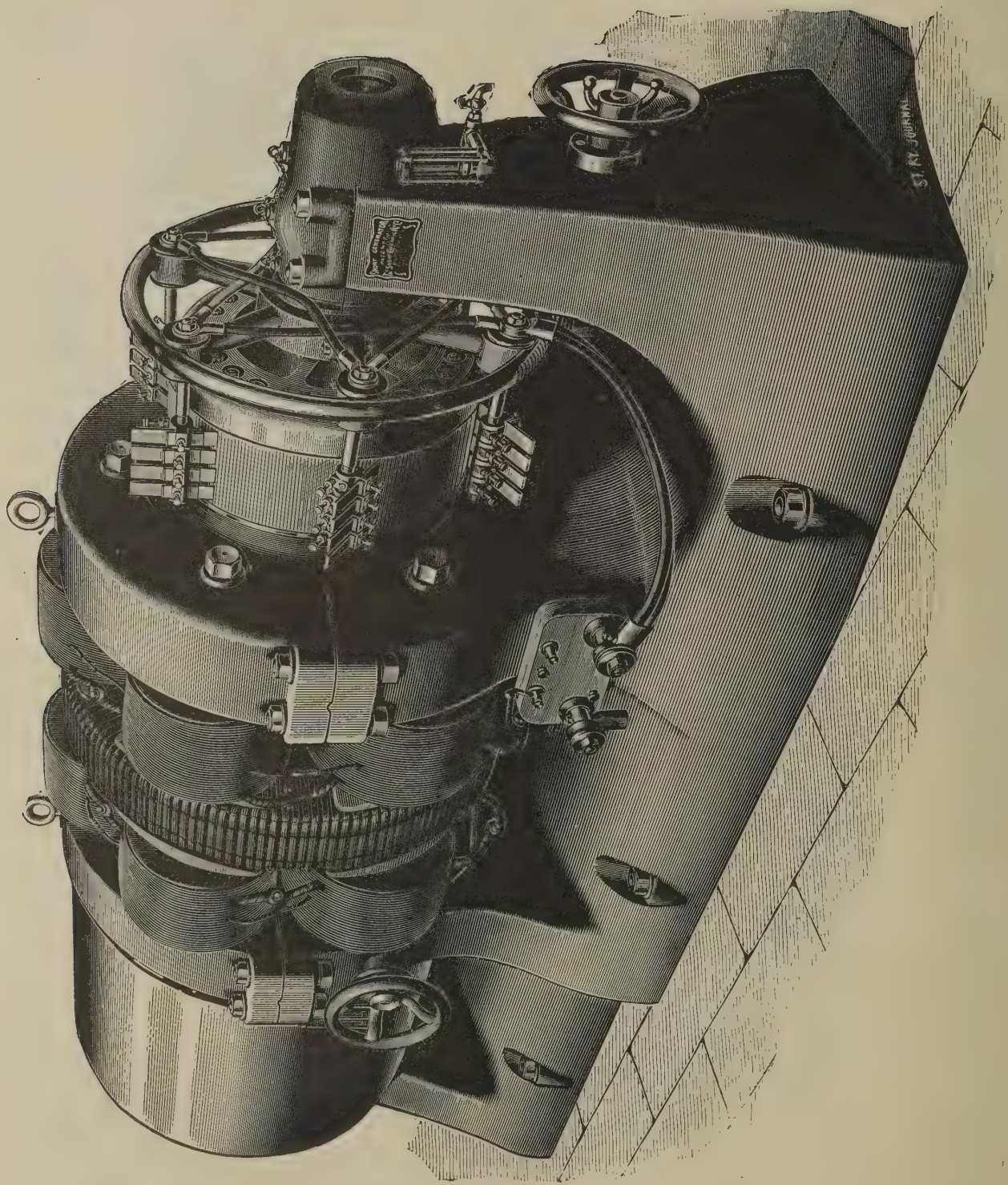


FIG. 12.—IMPROVED SHORT RAILWAY GENERATOR.

winding. Joints in the wire, when necessary, are electrically welded, no solder whatever being employed.

It will be noticed that practically all the metal in the machine is used in the magnetic circuit, thus making the weight of both iron and copper small. The air gap is also very small, so that the efficiency of the motor is high.

nets, twelve in number, are bolted to the frame, and carry both shunt and series coils. The armature, which is mounted on a shaft thirteen feet in length, is of the well known ring type, built by this company, and is fifty inches in diameter. The shaft runs in self oiling and self centering bearings. The centre bearing is provided with six thrust collars. The box in which this bearing runs is

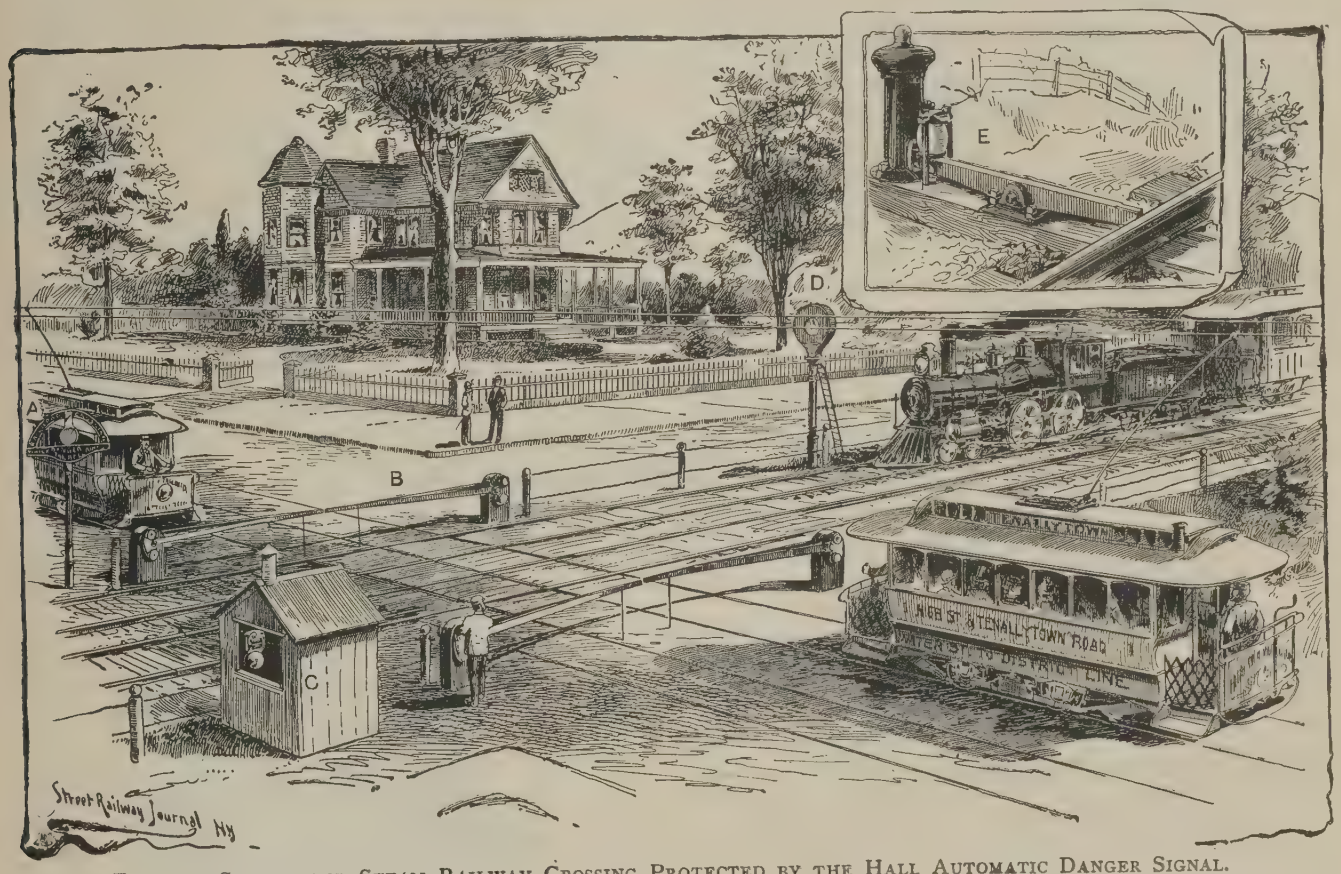


FIG. 13.—STREET AND STEAM RAILWAY CROSSING PROTECTED BY THE HALL AUTOMATIC DANGER SIGNAL.

The gears are of steel and run in an oil tight case. The small size of the motor permits two of them to be mounted on a truck of five feet wheel base and three feet gauge. The nominal capacity of the motor shown in the view is fifteen H. P., but other sizes are manufactured.

GENERATORS.

Fig. 12 illustrates a 300 H. P. generator lately put on the market by the Short Electric Railway Co., Cleveland O. This generator is capable of delivering a current of 500 amperes at a pressure of 500 volts. The frame is of a new design, thirteen feet in length and weighs ten tons. The field mag-

provided with a new device by means of which it can be easily adjusted. On the lower half of the box there is cast a feather which moves in a similar groove in the frame, and is operated by a screw which extends through the frame. This screw is provided with a hand wheel and jam nut by means of which it can be easily held and adjusted. The commutator is of large diameter (twenty-four inches) and contains 200 bars. The brushes are six in number and are carried and adjusted in a novel manner. A split wheel is provided, in the lower side of which are gear teeth which mesh into a pinion mounted on the shaft

which extends from the frame. On the outer end of this shaft are a wheel and jam nut by means of which the brushes can be easily and quickly adjusted and held. This generator is designed to run at 300 revolutions belted, and 250 revolutions when connected direct to an engine.

ELECTRIC CROSSING SIGNALS.

The Hall Signal Co., of New York, have devised a type of highway crossing signal which is especially adapted for use on cable and electric lines

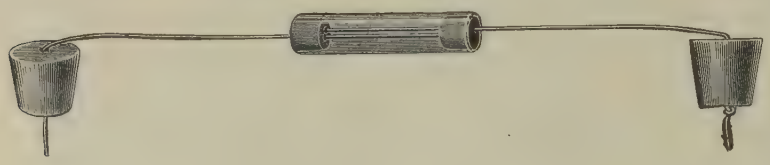


FIG. 14.—LIGHTNING ARRESTER FUSE.

where there is a possibility of the power failing while a car is crossing a steam track (Fig. 13). The automatic signal may be used alone or in connection with safety gates operated by a gate tender.

Ordinarily, an audible signal, A, is all that is necessary, and this usually consists of a signal stand, with a bell suitably housed, which is caused to ring by an approaching train, thus warning the car driver in time to prevent crossing in the face of danger. When used in connection with gates, B, it is arranged that a bell in the gateman's cab, C, rings, giving notice of the approaching train in time for the gateman to close the gates before the crossing is reached. In case the gateman fails to close the gates, a signal instrument, D, placed at a suitable distance from the crossing, and which stands at danger when the gates are open, stops the train before it arrives at the crossing.

The operation of the signal will be readily understood by an inspection of the accompanying engraving. The principal, or track, instrument is shown at E and consists of a wooden lever properly balanced and so placed that it will be depressed by the wheels of a passing train, its outer end at the same time forcing upward a piston which moves in a closed chamber, and communicates motion to a lever of the circuit closing apparatus. The piston operates in an air chamber having two apartments connected by a port, and so arranged that the confined air constitutes a cushion which prevents the piston rod from being thrown forcibly against the top cap, and also retards its fall and prevents injurious shocks. The track lever is confined between two rubber springs which are so compressed that any weight less than that imposed by the car wheels fails to operate the piston. The circuit being normally open, the operation of the lever conducts the current by means of a wire to the bell, which starts it ringing, and at the same time locks the instrument so that the bell continues to ring until the train shall have reached a second instrument on the other side of the crossing, which breaks the contact and silences the bell. The battery and interlocking instrument are usually located at the crossing. By a simple arrangement of interlocking and track instruments, the bell may be made to ring by the approach of a train from either direction on a single track.

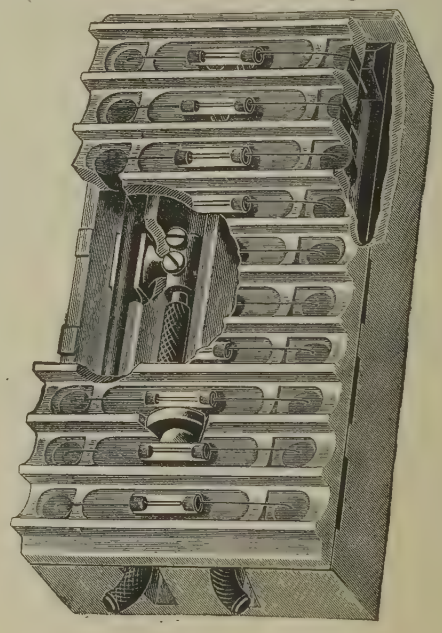


FIG. 15.—FULMEN ARRESTER.

These safety appliances have been in successful operation on a number of lines and seem to present an effectual way of reducing a serious danger element.

LIGHTNING ARRESTER.

In addition to the lightning arresters described on pp. 63 and 64, attention is called to the Fulmen

arrester, illustrated herewith (Figs. 14 and 15), which is constructed on the principle of providing a magazine of inexpensive discharge plates or fuses, so arranged that when one set of plates is destroyed, each set will successively become automatically connected to receive a lightning discharge.

The stationary parts of the apparatus, or the case, which may be attached to the wall of the power station, car body, cross arm or other position as the case may demand, consists of a porcelain base, having four channels, two of which are designed to receive the wire terminals, which connect the carbon rods in the other two channels, one to the line and the other to the ground, and a corrugated porcelain cover which contains a series of fuse arresters, and which is attached firmly to the base by a simple lug and spring bolt, so that it can be readily removed.

The arrester proper, constituting one set (Fig. 14) consists of two small brass wires, about two and a half inches long, with their inner ends lapping, but separated about one twentieth of an inch from each other. These form the discharge plates of the arrester, and are kept clean and dry by being sealed in a small glass tube, and are held in position properly spaced by means of rubber plugs which attach them to the porcelain cover. When in position the fuses approach, but do not touch the carbon vertical rods which form the line and ground terminals.

The individual fuses are brought into operative position by means of two wedge shaped pieces of carbon which rest against the ends of the top fuse and complete the connection between the terminal carbon rods. In operation, the atmospheric current jumps the space between the lapped ends of the fuse and starts a short circuit which instantly consumes the fuse, and allows the two carbon wedges to drop and adjust themselves to the next set, ready for a second discharge, and so on for ten consecutive discharges, which are considered more than sufficient for one storm.

In replacing fuses the cover is detached, thus avoiding the possibility of a shock from contact with the wires. The destruction of a single fuse in circuit is complete when acted upon by the arc as described, but the other fuses and porcelain pieces remain unharmed.

AUTOMATIC TRACK SWITCH.

This is a type of railway switch designed for use with cars propelled by animal or mechanical power, and is operated entirely by the car wheels, independently of any other mechanism attached to the car, or of any attention on the part of the driver. As will be seen from the accompanying illustration Fig. 16, the proper switching of the car is insured independently of the direction of the preceding car, or of any change of the switch by accident or otherwise, some of the cars having wheels with specially designed treads or flanges to secure that result.

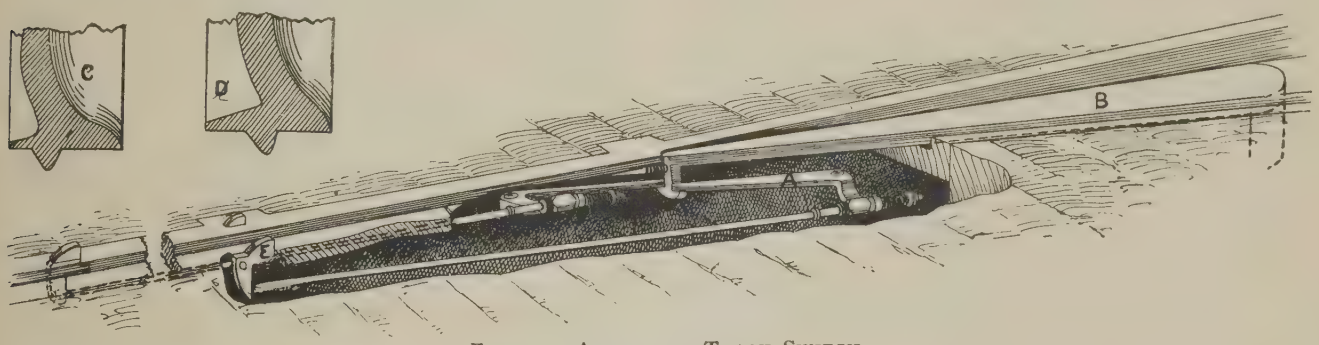


FIG. 16.—AUTOMATIC TRACK SWITCH.

The operating mechanism consists of switch keys or levers, E, pivoted within openings in the rail, and so placed as to project slightly above the rail, and in position to the right or left of the track groove to engage with the tread or flange of an ordinary, or specially designed wheel, C and D, by which they are depressed, and which in turn operate the switch tongue, B, through the medium of connecting rods and bell cranks, A. Spiral

springs are also provided for the adjustment of the levers and to prevent shock, and one is placed at the end of the tongue, which assists in throwing the tongue into position after passing the centre line, and holding it there. The mechanism is housed in a chamber beneath the rail, or in a specially constructed rail, having a removable side by which access can be had for the adjustment or repair of the parts.

It will be seen that the device admits of any number of key combinations. For instance, the first key, which is operated alike by all cars, may be arranged to throw the switch in one direction, and provide for leading off such cars as are equipped with ordinary wheels, and two other keys located between the first key and the switch tongue in position to be operated respectively by treads or flanges of greater width than required to operate the first key, and designed to throw the tongue in the opposite direction; the keys and tongue being so located relative to each other and to the car wheels that the car may set the switch by the first key and reset it for itself by one of the last keys. The keys are so coupled together that the operation of the second key sets the first one in position for the next car.

This is one of the latest automatic switch devices that has been brought to the attention of the public, and although it has not had the test of long service to recommend it, it seems to possess considerable merit. The device was originated by C. E. Garey, master mechanic of the Dry Dock, East Broadway & Battery Railroad Co. of New York.

COST OF ELECTRIC RAILWAY CONSTRUCTION.

The following general estimates are submitted as a basis on which to compute the cost of building and operating an electric trolley line in city streets under ordinary conditions. As was stated on p. 132, in connection with an estimate for cable construction, in order to make a close and accurate estimate of the cost of any particular line all the conditions must be known. Not so many conditions, however, affect the cost of electric construction. The substructures are not usually disturbed, and the character of the soil does not usually affect the cost, save in exceptional cases where rock formation interferes with the setting of poles. Under ordinary conditions one mile of double track, first class straight street construction, including iron poles, overhead wires, return wire rail connections, paving, etc., excluding engineering, will cost about $60,000.

Approximate cost for building and equipping three miles of double track road for the overhead electric service, power station located near centre of line:

ROAD BED.

15,840 lineal feet broken stone foundation, six inches deep, including sub-excavations for same, with stone ballast between ties, at 90 cents per foot	$14,256.00
15,136 ties (2 ft. centres) 5 × 7 ins. at 45 cents	6,811.20
1,056 double joint ties, at 75 cents	792.00
31,680 ft. 78 lb. per yard steel girder rail, including splice bars, bolts, spikes, chairs, tie rods and all iron employed in the construction, freight, etc., at $1.42 per foot	44,985.60
Six miles electrical construction, including one continuous copper return wire in each track thoroughly bonded to each rail, at $500 per mile	3,000.00
Labor, teams, superintendence, etc., at 30 cents per foot	9,504.00
28,158 sq. yds. granite block paving, including material, at $3	84,474.00
Total	$163,822.80

SPECIAL STREET CONSTRUCTION.

Two crossover switches at $525	$1,050.00
One double track crossing	270.00
180 degs. of double track curve	491.50
Total	$1,811.50

OVERHEAD STREET CONSTRUCTION.

270 iron pipe poles, ninety to the mile, extra heavy, 6 × 5 × 4 ins. 28 ft. long, including fittings, at $26	$7,020.00
8 iron terminal and curve poles at $50	400.00
Setting 278 poles with concrete foundation within curb line and replacing flagging, at $7	1,946.00
Painting 278 poles at $1.00	278.00
6 miles No. 0 (B. & S) gauge trolley wire, 10,224 lbs., at 15 cents per pound	1,533.60
Span wire, (streets 50 ft. wide) $\frac{5}{16}$ 7 strand steel galvanized 2,200 lbs., at 5½ cents per pound	121.00
*4 miles feed wire, 15,600 lbs., at 17 cents per pound	2,652.00
Strain and anchor wire, 270 lbs., at 4 cents per pound	10.80

*With ordinary traffic no feed wire would be required for three miles of road, but with thirty cars it would be necessary.

3 miles line and insulating appliances, lightning arresters, etc., double track, at $300	900.00
Labor, stretching trolley and feed wire and attaching insulating appliances, 3 miles, at $500 per mile	1,500.00
Total	$16,361.40

SPECIAL OVERHEAD CONSTRUCTION.

6 trolley switches at $3	$ 18.00
2 90 deg. double track curves, at $75	150.00
Guard wire and guard span half the line, with connections	250.00
Total	$418.00

POWER HOUSE AND PLANT.

Real estate	$10,000.00
House 175 × 100 ft	25,000.00
Steam plant; two slow speed, compound, condensing engines and boilers with their foundations, smoke stack, condensing apparatus, pumps, belting and countershaft, freight and labor, 35 H. P. per car, 1,050 H. P., including 20 per cent. reserve, at $65	68,250.00
or	
Four high speed engines and boilers with their foundations, smoke stack, feed water heaters, pumps, belting (direct), 35 H. P. per car 1,050 H. P., including 20 per cent. reserve, at $55, $57,750.00.	
Electrical equipment, including generators, switchboard and all appliances, 30 H. P. per car, including 20 per cent. reserve, 900 H. P., at $35	31,500.00
Total	$134,750.00

ROLLING STOCK AND EQUIPMENT.

(Trains running on four minutes' headway.)

15 sixteen foot motor cars at $1,000	$15,000.00
15 motor trucks at $275	4,125.00
30 twenty H. P. motors (two to each car), all electrical appliances in position, at $1,250	37,500.00
15 coaches (trailers) with trucks, at $1,200	18,000.00
Total	$74,625.00

CAR BARN AND REPAIR SHOPS.

Real Estate	$2,500.00
Car House, fire proof	25,000.00
Pits, tracks and switches, with main track connections	4,000.00
Repair shops, equipment, (*a*) wood working department	4,500.00
(*b*) Iron working department	4,000.00
Total	$40,000.00

AUXILIARY APPLIANCES.

One electric snow plow and sweeper	$5,000.00
Other snow appliances	1,000.00
One wrecking wagon, tools and team	800.00
One high wagon, line tools and horse	600.00
One light express wagon and horse	350 00
One heavy wagon and team	500.00
Two carts	100.00
Track tools and other appliances	300.00
Total	$8,650.00

SUMMARY.

Road bed	$163,822.80
Special street construction	1,811.50
Overhead construction	16,361.40
Special overhead construction	418.00
Power house and plant	134,750.00
Rolling stock and equipment	74,625.00
Car barn and repair shops	40,000.00
Auxiliary appliances	8,650.00
Engineering, legal and miscellaneous, at $5,000 per mile	15,000.00
Total for three miles double track	$455,438.70

In comparing the above estimate with the cost of equipping a cable line of the same length, as given on page 134, a portion of the items for car barn, repair shops, auxiliary appliances and engineering should be added to the cable estimate.

The cost for constructing a longer line will be in direct proportion to the number of miles, and the cost for power plant will increase according to the number of cars, but the cost of real estate, power and car house will remain constant for a considerable increase of mileage or traffic.

A road three miles in length, with fifteen trains (motor and trail cars) will cost, under ordinary conditions, about $478.50 a day to operate, allowing for depreciation. The type of motor, grades and character of the management will increase or decrease these figures, as the case may be. There are lines in successful operation which cost considerably more than this amount.

The principal items of expense will be about as follows :

Twelve tons of coal (2,240 lbs) at $2.50	$30.00
Water, oil and grease for engines, generators, cars and motors	10.00
*Depreciation of plant and rolling stock	38.00
Sixty-six motormen and conductors at $2.00	132.00
Engineers, firemen and dynamo tenders	25.00
Car house service, inclusive of cleaning, inspection, etc	20.00

*A sum which, if put out at compound interest at three per cent., at the end of each year, would provide, in twenty years, for renewing the material subject to depreciation.

Power and car house expenses	6.00
Track service	8.00
Repairs engines, generators, line machinery electric power equipment and miscellaneous	13.00
Repairs cars, trucks and motors	78.00
Repairs track, overhead construction and buildings	47.00
Track cleaning, train and shop expenses	14.00
Injury to persons and property	10.00
Legal, secret service and insurance	8.00
Licenses and taxes	7.00
General and miscellaneous expenses	32.50
Total	$478.50

With trains on four minutes' headway, each train would make 110 miles per day, and fifteen trains would make 1,650 train miles or 3,300 car miles. The total operating expenses would, therefore, be 14.5 cents per car mile.

About one-third the cost of operating an electric line remains constant by a limited increase or decrease in the traffic, while the other two-thirds varies as the traffic varies.

THE END.

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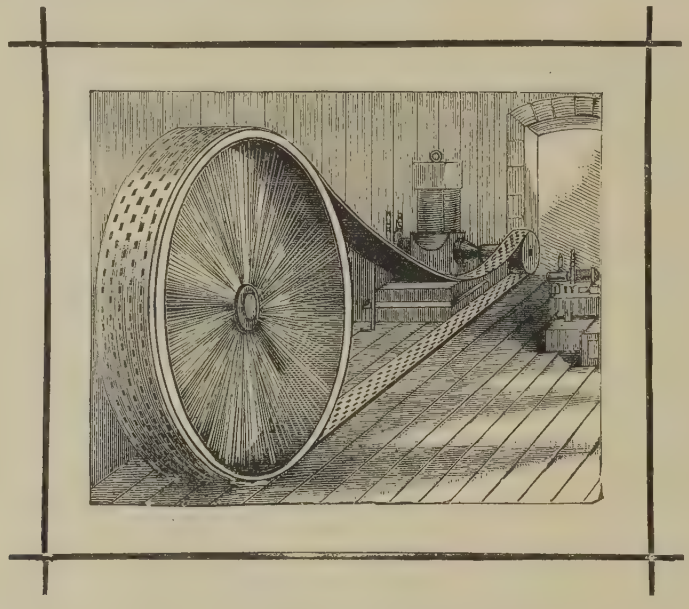

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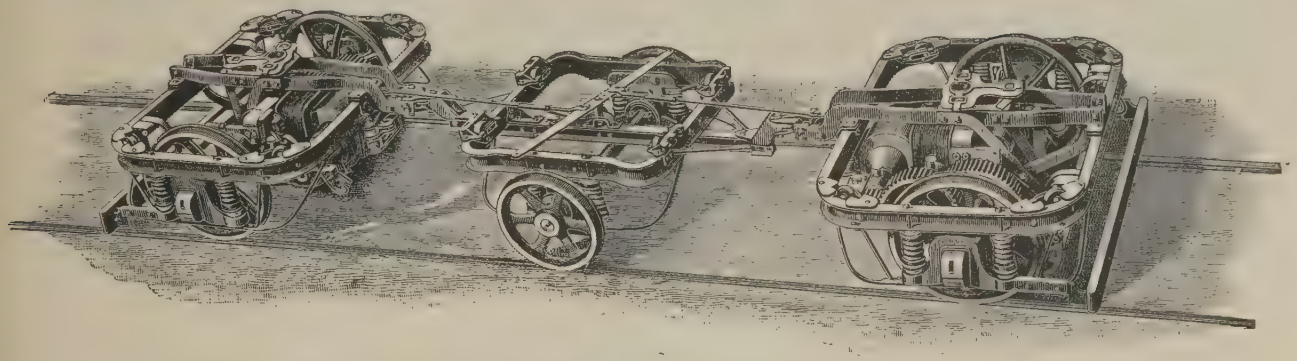

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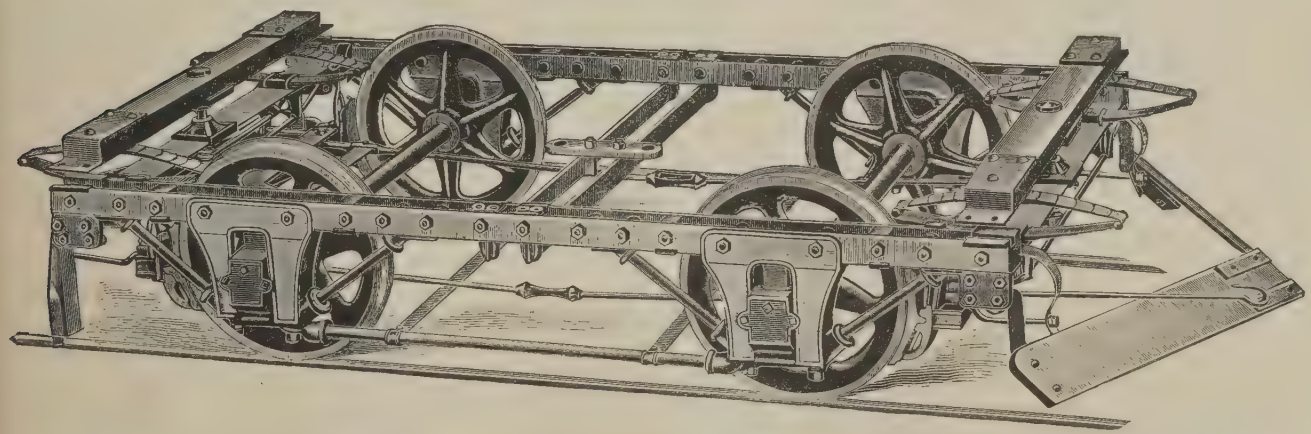

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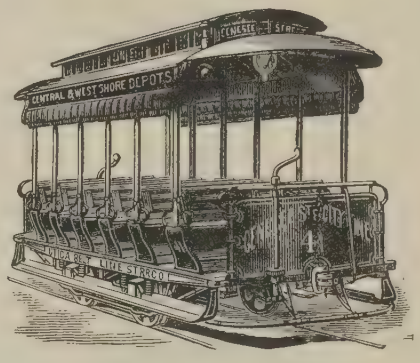

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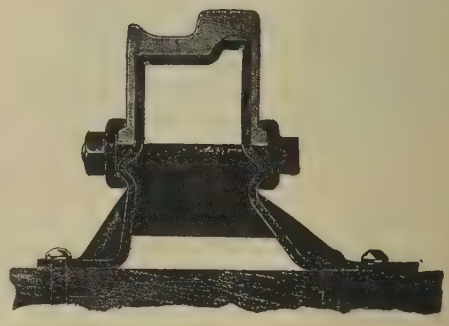

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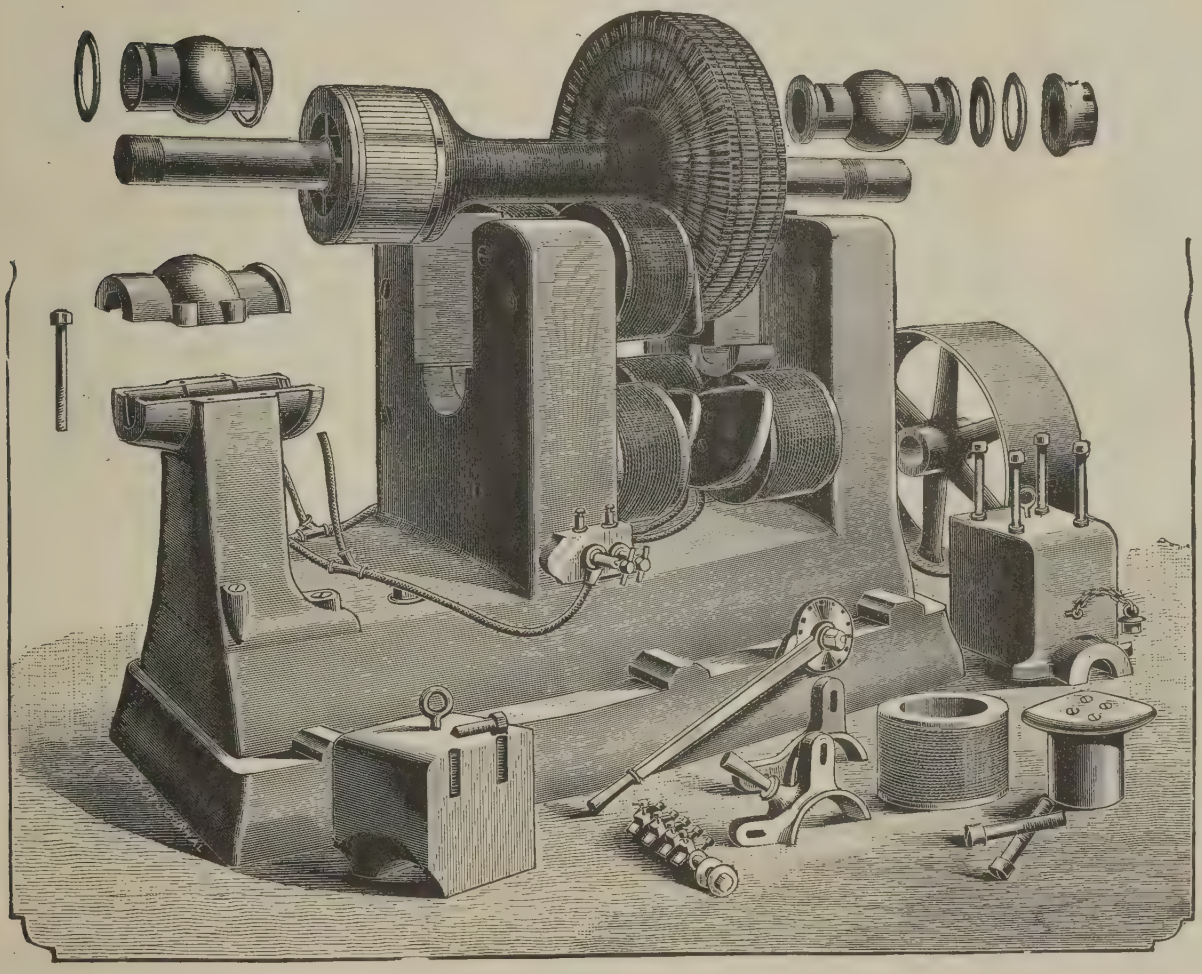

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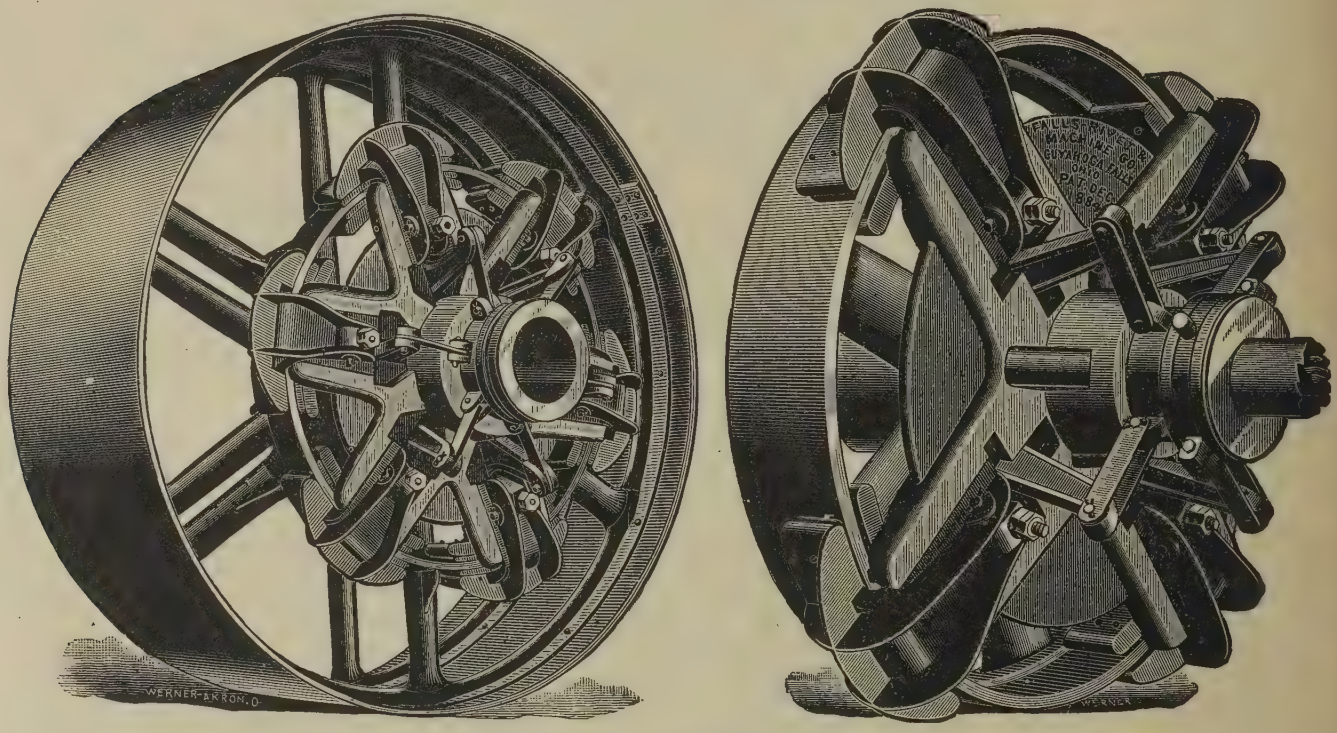

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THEIR SPECIAL AWARD FOR THE MOST DESERVING INVENTION OF THE YEAR.

THE DUPLEX STREET RAILWAY TRACK IS IN USE OR UNDER CONTRACT ON THE FOLLOWING ROADS AND CITIES:

New York & Harlem R. R. Co., Fourth Avenue, New York.
New Orleans & Carrollton Railroad Co., New Orleans, La.
Rochester Railroad Co., Rochester, N. Y.
Camden Horse Railroad Co. (Electric Division), Camden, N. J,
Atlantic Avenue Railroad Co., Brooklyn, N. Y.
Lakeside Electric Railway Co., Fort Wayne, Ind.
Steinway Railway Co., Astoria, L. I.
Lake Roland Elevated Railroad Co., Baltimore, Md.,
And in Kansas City, Mo.

CORRESPONDENCE INVITED.

GENERAL OFFICES, 51 WALL ST., NEW YORK.

From the Journal of the Franklin Institute, June, 1892.

DUPLEX STREET RAILWAY TRACK.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS.

[No. 1,643.]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 6, 1892.

The Sub-Committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination

THE DUPLEX STREET RAILWAY TRACK,

report, That the system embraces a form of construction for street railways that dispenses with wooden sills and crossties, and substitutes therefor metal chairs and tie-bars as supports and braces, for a system of double rails of peculiar construction, in which the head and flange rails are separate, each having a wide depending web directly under the load bearing surface. These two sections, when united, form a complete rail, making a very stiff longitudinal stringer, laid to break joints, so that when the head sections meet they are supported by the solid portion of the flange section, and where the latter join they are covered partially by the solid head section, thus practically forming a jointless track of uniform strength and elasticity throughout its entire length.

THE CLAIMS OF SUPERIORITY ADVANCED FOR THIS SYSTEM, BRIEFLY STATED, APPEAR UNDER THE FOLLOWING HEADS:

(1) "**Durability and permanence,** inherent to an all-metal system." This claim passes without question.

(2) "**Smoothness and stability** of the track, which is absolutely free from weak points."

When a track is constructed so that the ends of the rails cannot yield to the passing load, the worst of all track-destroying causes is removed, and such a road must retain its smoothness and stability until the rails are entirely worn out throughout their length.

(3) "**Increased vertical** and **lateral strength** without increase of metal."

(4) "**Freedom from torsional strain,** the bearing surfaces being directly supported by the vertical webs."

(5) "**Increased wearing capacity of head rail.**"

On tracks constructed so that wagons cannot travel upon them, or where the wagon travel is much lighter than the car service, the head of the rail will wear out most rapidly; when this occurs upon a single girder rail the entire rail must be discarded as scrap, while with the Duplex system, only the head rail need be renewed, and the discarded part is but half the weight of the single girder.

(6) "In renewal, the **discarding of the worn portion only** is necessary."

The advantage of retaining either half of the rail in service until it is worn out, adds greatly to the life and economy of such a track.

(7) "**Perfect alignment and accurate maintenance of gauge** with requisite freedom for expansion and contraction."

The union of the rails with the tie-bars and keys at the chairs is such that, while the rails are firmly seated in the chairs and securely held down by the keys, the eyes in the rail-webs being longer than the width of the keys, ample play for expansion is provided.

(8) "**Simplicity of construction** which expedites the track laying and reduces the disturbances of the public streets."

Every piece of the Duplex track is of the simplest form and inexpensive to make, and in the construction of a mile of track but 7,850 pieces are required, while some of the permanent single girder tracks are made up of over 26,000 pieces, and the common tram rail uses 17,406 pieces per mile. In excavating for these tracks the quantity of earth to be removed bears about the same ratio, viz.: for the Duplex track 300 cubic yards, and for the others 1,064 cubic yards and 932 cubic yards, respectively. These advantages bring the cost of the superior all-metal Duplex track within the cost of the ordinary tram track.

(9) "**Maintenance of absolute contact of metal,** which obviates the necessity of 'bonding joints' for electrical traction."

This claim is doubtless well founded; the method of connecting the rails at their ends is such that for electrical service the track is found to be practically and permanently as one continuous rail.

(10) "**A reasonable first cost, and great saving in maintenance.**"

For reasons above stated, this claim must be conceded.

From a careful examination of this system and an inspection of tracks in practical use, it is evident that much that has long been desired in the direction of a better and more lasting construction, permanent smoothness and strength equal to the heavy traffic that they are subject to, has been carefully and ably worked out upon a thoroughly practical and economical line, in every detail.

The special requirements of electrical traction and cable service appear to be fully met, so that we have an excellent substitute for every objectionable form of track now commonly used.

We therefore respectfully recommend the grant to the inventor of the award of the John Scott Legacy Premium and Medal.

H. R. HEYL, *Chairman.*

SPENCER FULLERTON, J. M. EMANUEL, G. MORGAN ELDRIDGE,
ARTHUR BEARDSLEY, CHAS. E. RONALDSON, L. L. CHENEY.

Adopted, May 4, 1892.

ARTHUR BEARDSLEY, *Chairman of the Committee on Science and the Arts.*

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			Boilers.	H. P.
WEST END STREET RAILWAY CO., Boston, Mass	3	orders, 1889–1890,	26	6,500
THE MERRIMAC VALLEY STREET RAILWAY CO., Lawrence, Mass	2	" 1891–1892,	3	480
THE PORTLAND STREET RAILWAY CO., Portland, Me		April, 1891,	2	250
GLOBE STREET RAILWAY CO., Fall River, Mass		1892,	3	675
LYNN & BOSTON RAILROAD, Lynn, Mass		Jan., 1892,	6	1,500
" " " Chelsea, Mass		"	6	1,500
HARLEM BRIDGE, MORRISANIA & FORDHAM RAILROAD, New York City		"	4	1,000
BROOKLYN CITY RAILROAD CO., Brooklyn, N. Y	2	orders, 1891–1892,	16	5,000
ATLANTIC AVENUE RAILROAD CO., Brooklyn, N. Y		April, 1892,	6	1,500
THE ALBANY RAILWAY, Albany, N. Y	2	orders, 1889–1892,	6	750
TROY & LANSINGBURG RAILROAD CO., Troy, N. Y	3	" 1889–1891,	5	864
ROCHESTER RAILWAY CO., Rochester, N. Y	2	" 1891–1892,	2	808
CROSSTOWN STREET RAILWAY CO., Buffalo, N. Y		Aug., 1890,	4	1,000
SEA SHORE ELECTRIC RAILWAY CO., Asbury Park, N. J		March, 1892,	2	640
PITTSBURGH & BIRMINGHAM TRACTION CO., Pittsburgh, Pa		July, 1890,	4	1,000
BRADDOCK ELECTRIC RAILWAY CO., Braddock, Pa		July, 1891,	1	164
ECKINGTON & SOLDIERS' HOME RAILROAD CO., Washington, D. C		Jan., 1889,	1	136
GLEN ECHO RAILWAY CO., Washington, D. C	2	orders, 1890–1891,	3	312
ROCK CREEK RAILWAY CO., Washington, D. C		Sept., 1890,	3	375
THE CINCINNATI STREET RAILWAY CO., Cincinnati, O	2	orders, 1890,	5	1,500
COLUMBUS CONSOLIDATED STREET RAILROAD CO., Columbus, O	2	" 1890–1891,	6	1,076
CITIZENS' STREET RAILWAY CO., Indianapolis, Ind		Aug., 1891,	2	600
AURORA STREET RAILWAY CO., Aurora, Ill	2	orders, 1890–1891,	4	832
STREATOR RAILWAY CO., Streator, Ill		April, 1890,	2	208
NEGAUNEE & ISHPEMING STREET RAILWAY CO., Negaunee, Mich		Sept., 1891,	2	208
THE DOUGLAS COUNTY STREET RAILWAY CO., Superior, Wis		June, 1891,	3	445
ST. PAUL CITY RAILWAY, St. Paul, Minn		April, 1890,	8	2,176
DULUTH STREET RAILWAY CO., Duluth, Minn	3	orders, 1890–1892,	7	1,072
ST. PAUL & WHITE BEAR RAILWAY, North St. Paul, Minn		March, 1892,	2	184
PEOPLE'S STREET RAILWAY, St. Joseph, Mo		May, 1889,	4	832
THE NORTHEAST RAILWAY CO., Kansas City, Mo		Sept., 1889,	2	250
THE AUGUSTA RAILWAY CO., Augusta, Ga		March, 1890,	1	150
THE COAST LINE RAILWAY, Savannah, Ga		March, 1892,	2	500
CITIZENS' RAILWAY CO., Waco, Tex		Aug., 1890,	2	240
TACOMA RAILWAY & MOTOR CO., Tacoma, Wash		May, 1890,	4	656
BILBAO ELECTRIC TRAMWAYS, Bilbao, Spain		Feb., 1889,	2	146
EAGLEHAWK ELECTRIC TRAMWAY CO., Sandhurst, Victoria, N. S. W		April, 1889,	3	90

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WASHINGTON & GEORGETOWN RAILROAD, Washington, D. C	3	" 1889–1891,	13	1,956
CLEVELAND CITY CABLE RAILWAY CO., Cleveland, O		March, 1890,	3	1,086
THE VALLEY CITY STREET & CABLE RAILWAY CO., Grand Rapids, Mich		April, 1891,	4	781
CHICAGO CITY RAILROAD, Chicago, Ill		April, 1881,	4	1,000
ST. PAUL CITY RAILWAY CO., St. Paul, Minn	2	orders, 1888–1890,	11	2,800
MINNEAPOLIS STREET RAILWAY CO., Minneapolis, Minn		Sept., 1889,	5	1,360
GRAND AVENUE RAILWAY CO., Kansas City, Mo	2	orders, 1886–1888,	4	800
METROPOLITAN STREET RAILWAY CO., Kansas City, Mo	3	" 1886–1888,	9	1,800
INTERSTATE CONSOLID'T'D RAPID TRANSIT RAILWAY CO., Kansas City, Mo		Aug., 1887,	2	400
PEOPLE'S CABLE RAILWAY CO., Kansas City, Mo		Aug., 1887,	3	600
HOLMES STREET RAILWAY CO., Kansas City, Mo		Feb., 1889,	2	350
DENVER CITY CABLE RAILWAY CO., Denver, Col	2	orders, 1889–1891,	4	1,600
HOUSTON CITY STREET RAILWAY CO., Houston, Tex	2	" 1890–1892,	3	492
MARKET STREET CABLE RAILWAY, San Francisco, Cal	2	" 1882–1887,	6	1,500
PIEDMONT CABLE CO., San Francisco, Cal		July, 1889,	3	438
CALIFORNIA STREET CABLE CO., San Francisco, Cal		May, 1890,	3	360
PATENT CABLE TRAMWAY CORPORATION, Highgate, London, England	2	orders, 1883–1884,	3	153
EDINBURGH NORTHERN CABLE TRAMWAY, Edinburgh, Scotland	2	" 1886–1891,	1	400
COMPAGNIE DES LOCOMOTIVES SANS FOYER, Courbevoie, France		Jan., 1889,	2	156
" " " " Nord de la Seine, St. Germain, France		May, 1889,	2	171
COMPAGNIE DES TRAMWAYS DU DÉPARTEMENT DU NORD, Roubaix, France		June, 1886,	3	135
COMPAGNIE DES OMNIBUS ET TRAMWAY, Lyons, France	3	orders, 1887–1888,	3	152
THE MELBOURNE TRAMWAYS, Richmond Line, Australia, Melbourne		Nov., 1884, July, 1885,	6	1,040
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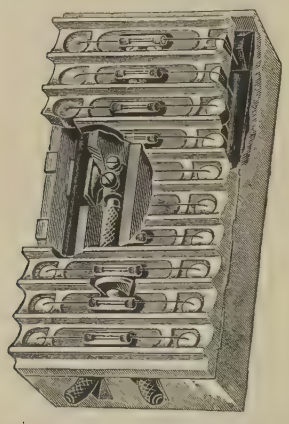

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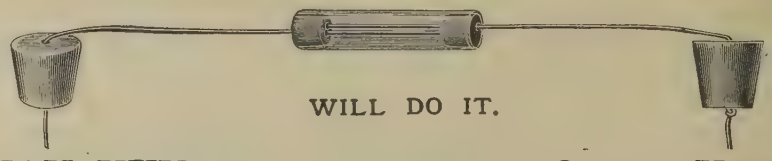

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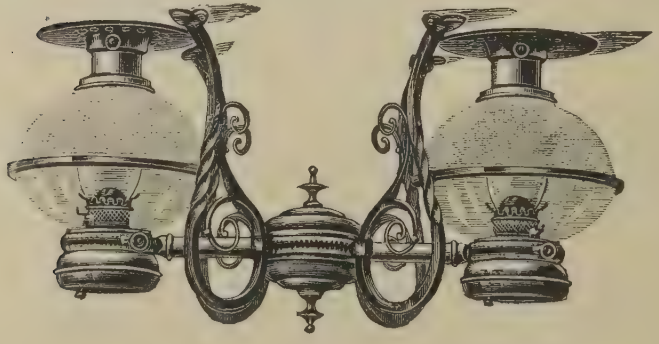

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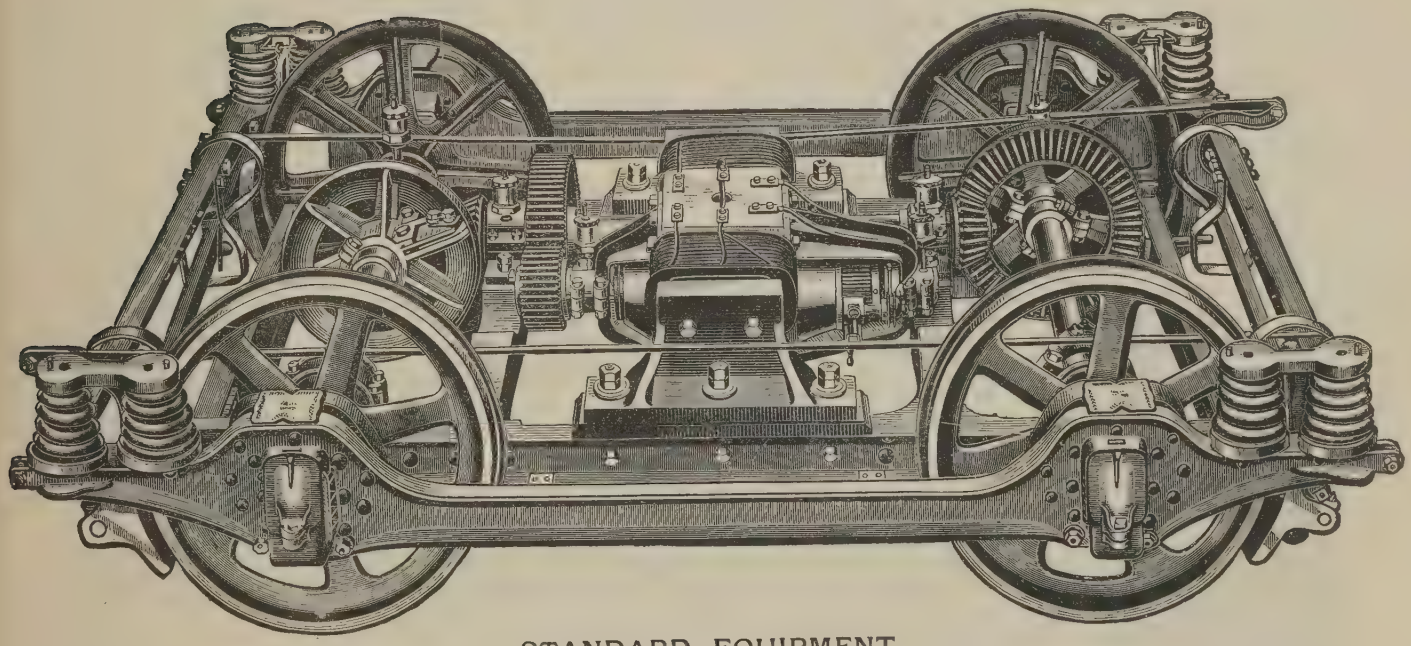

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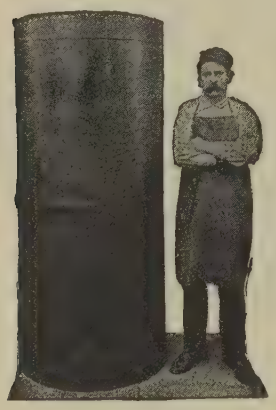

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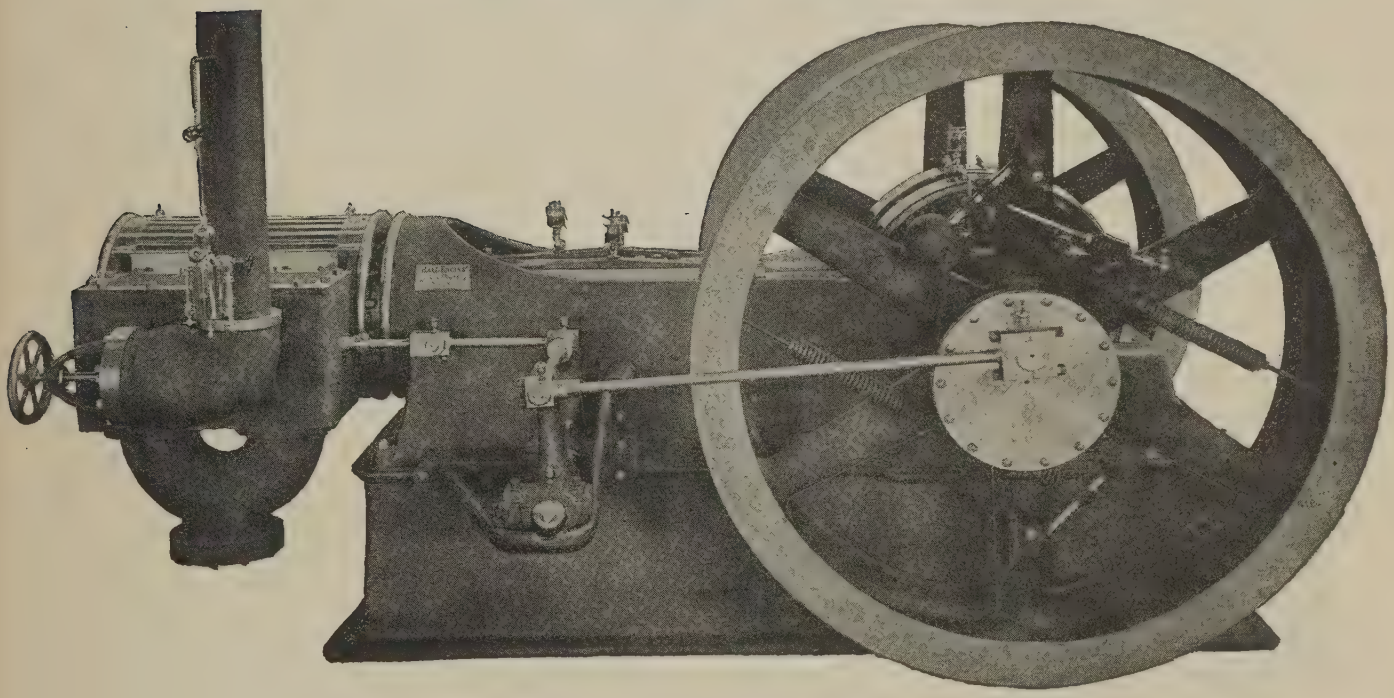

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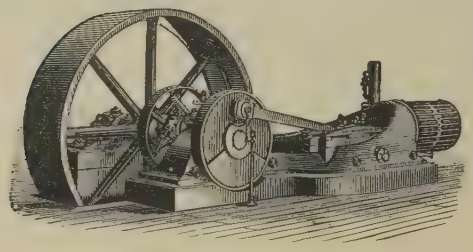

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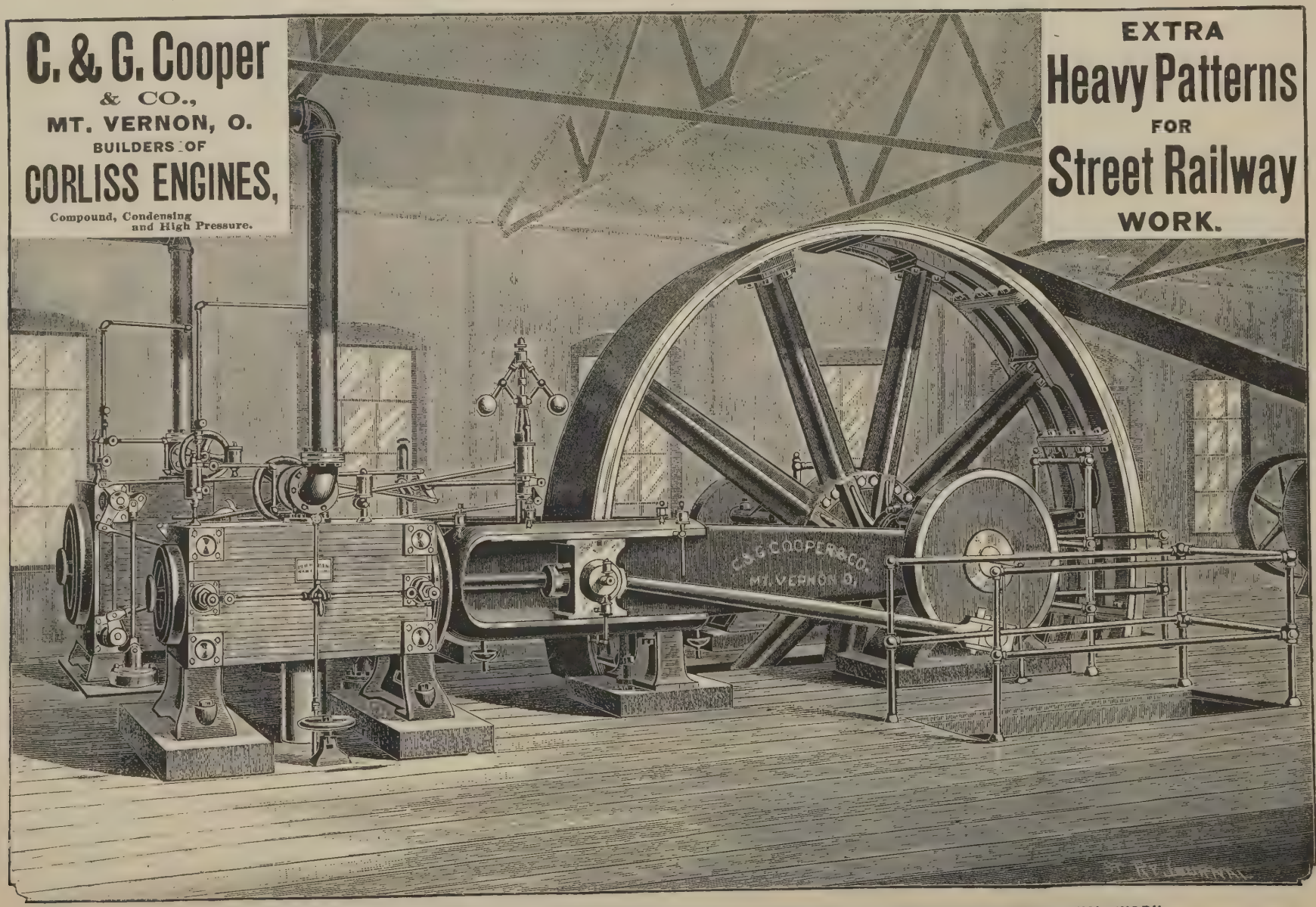

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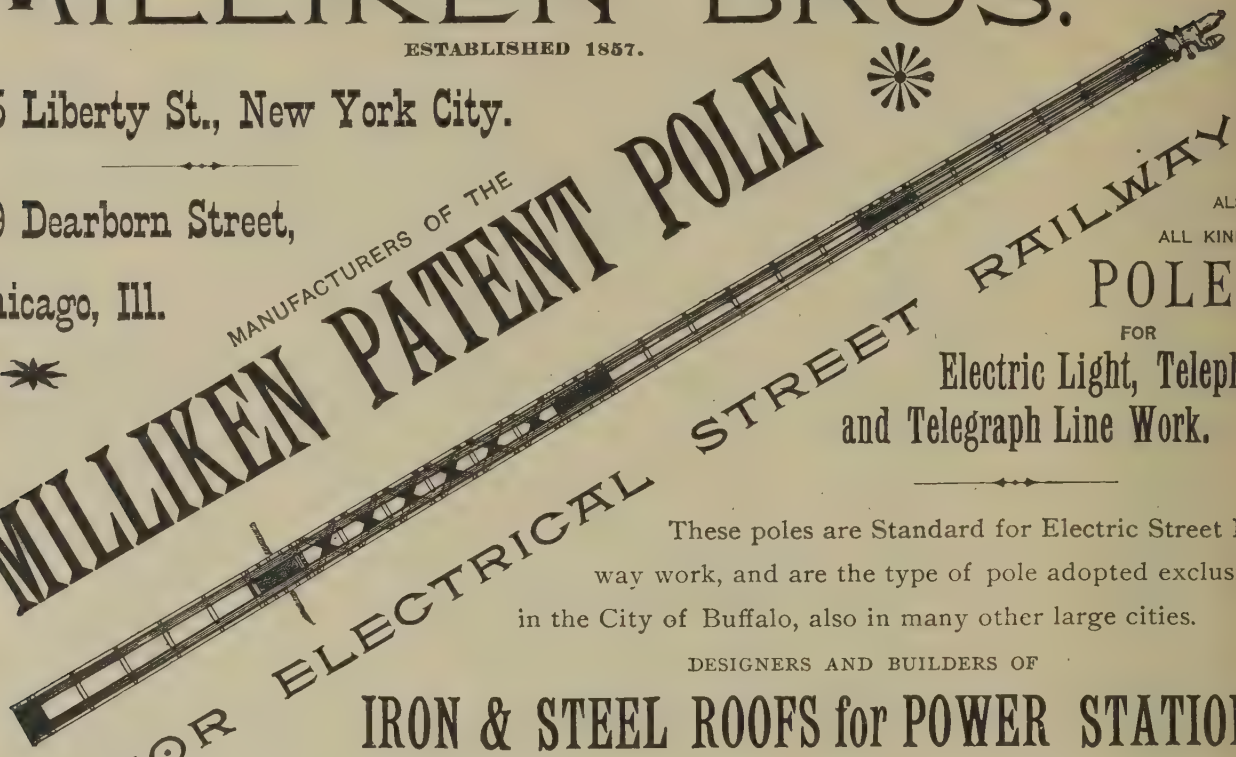

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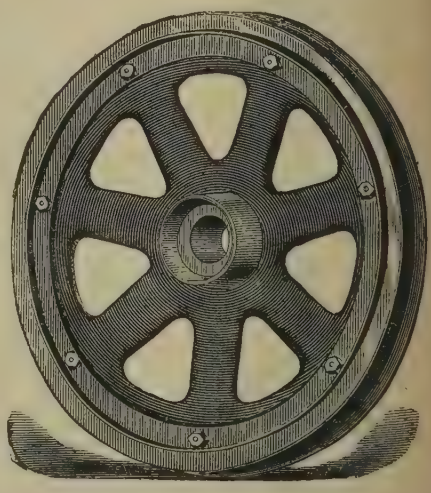

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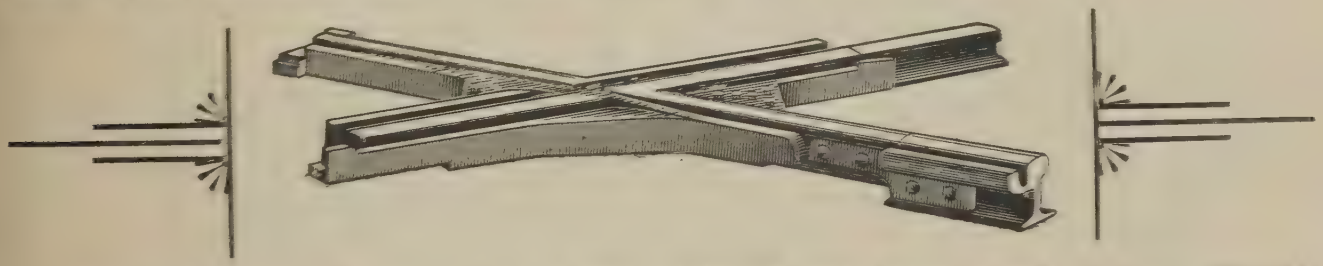

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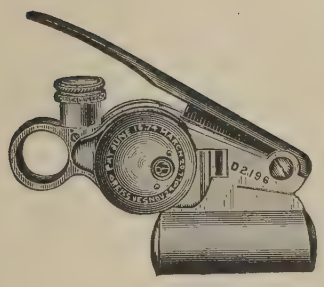

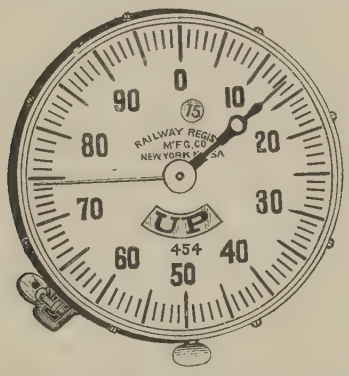

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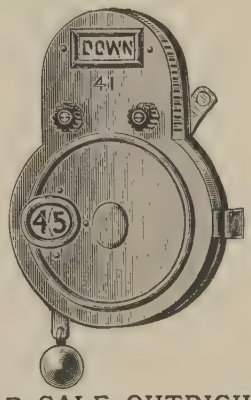

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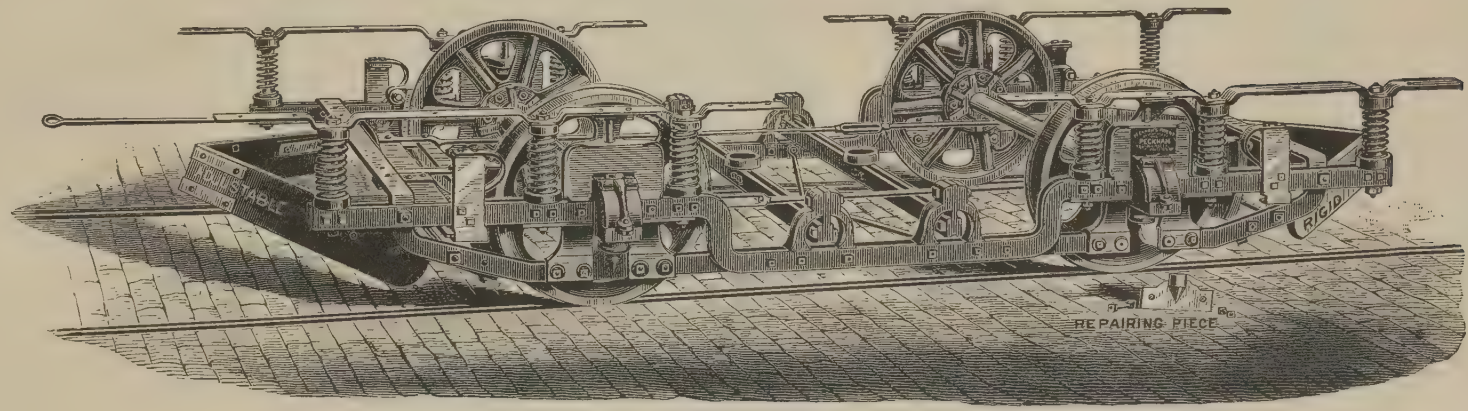

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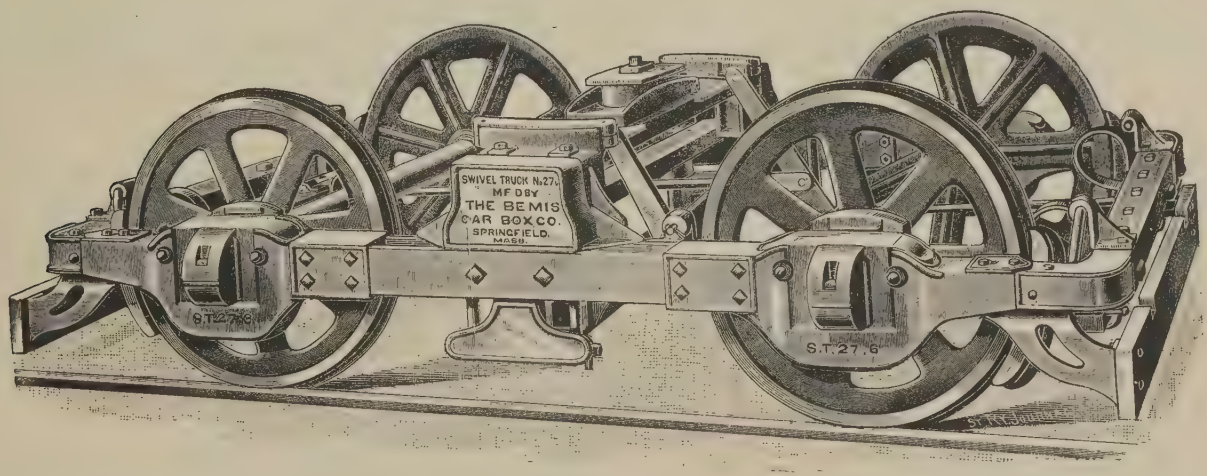

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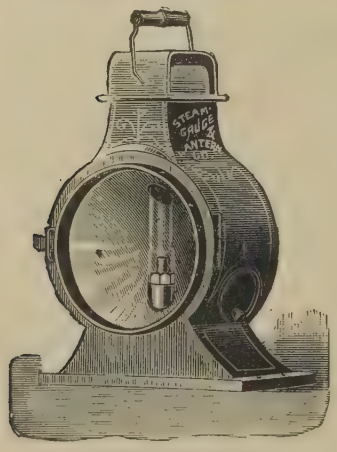

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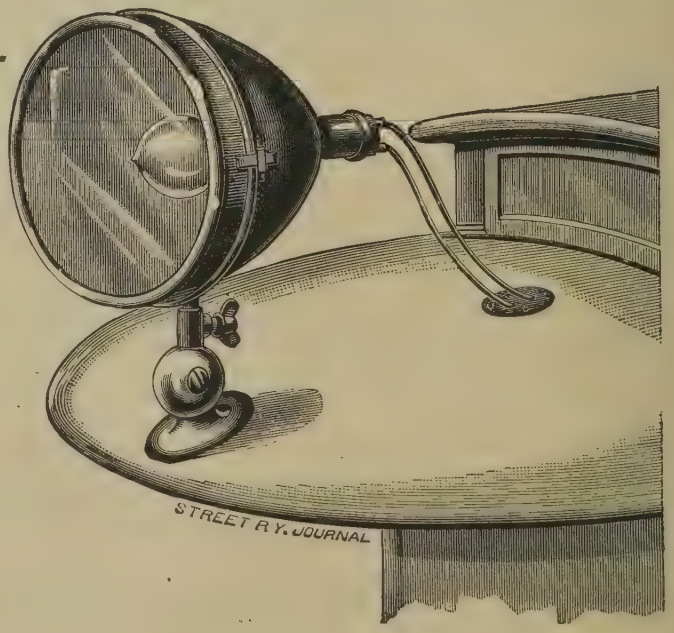

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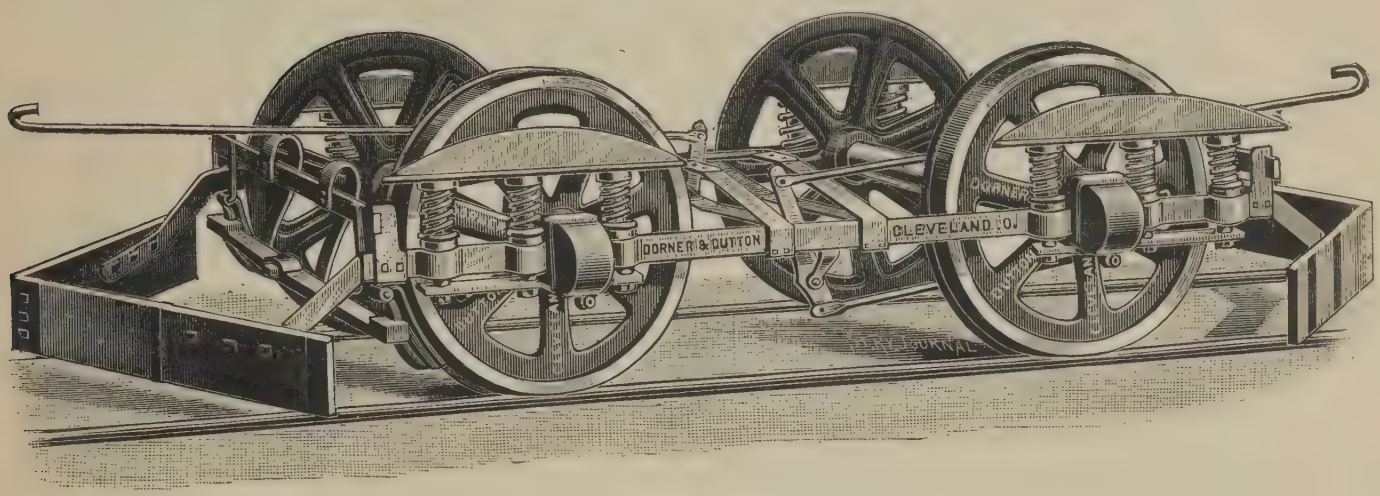

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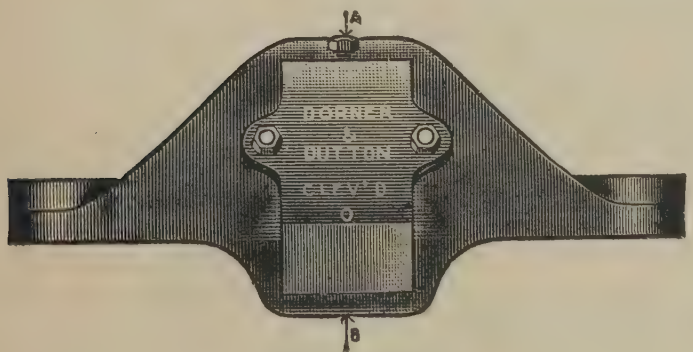

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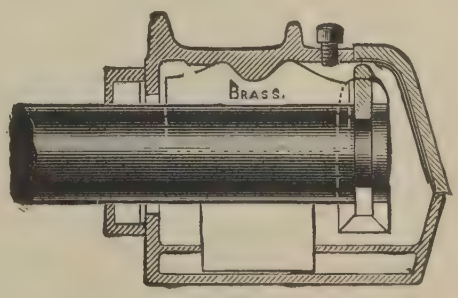

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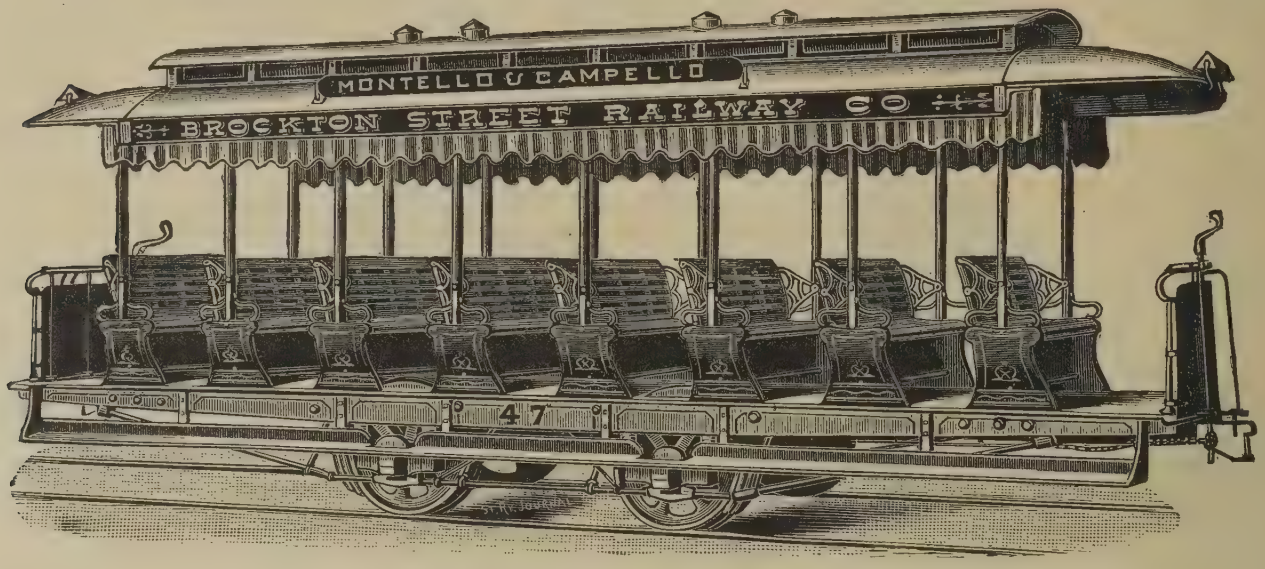

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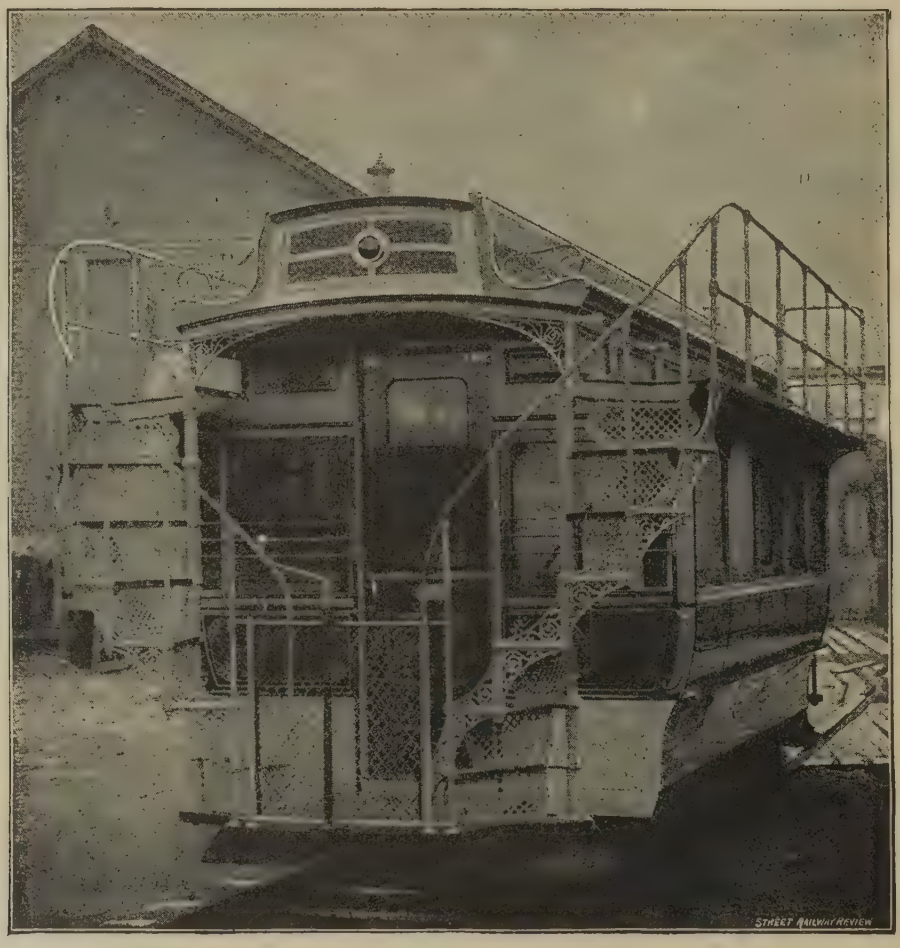

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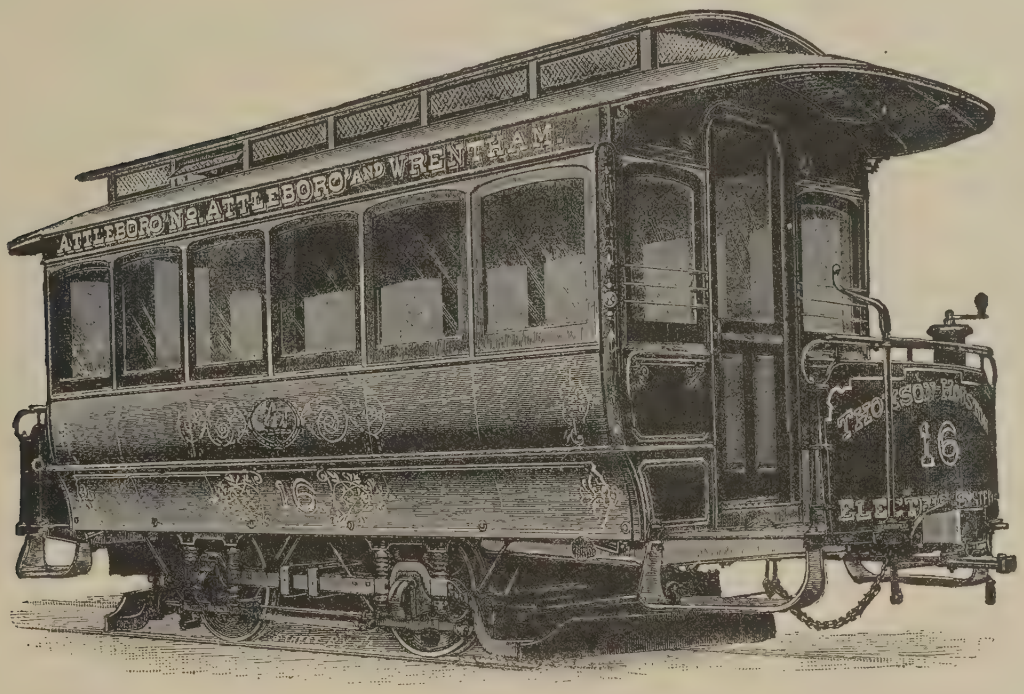

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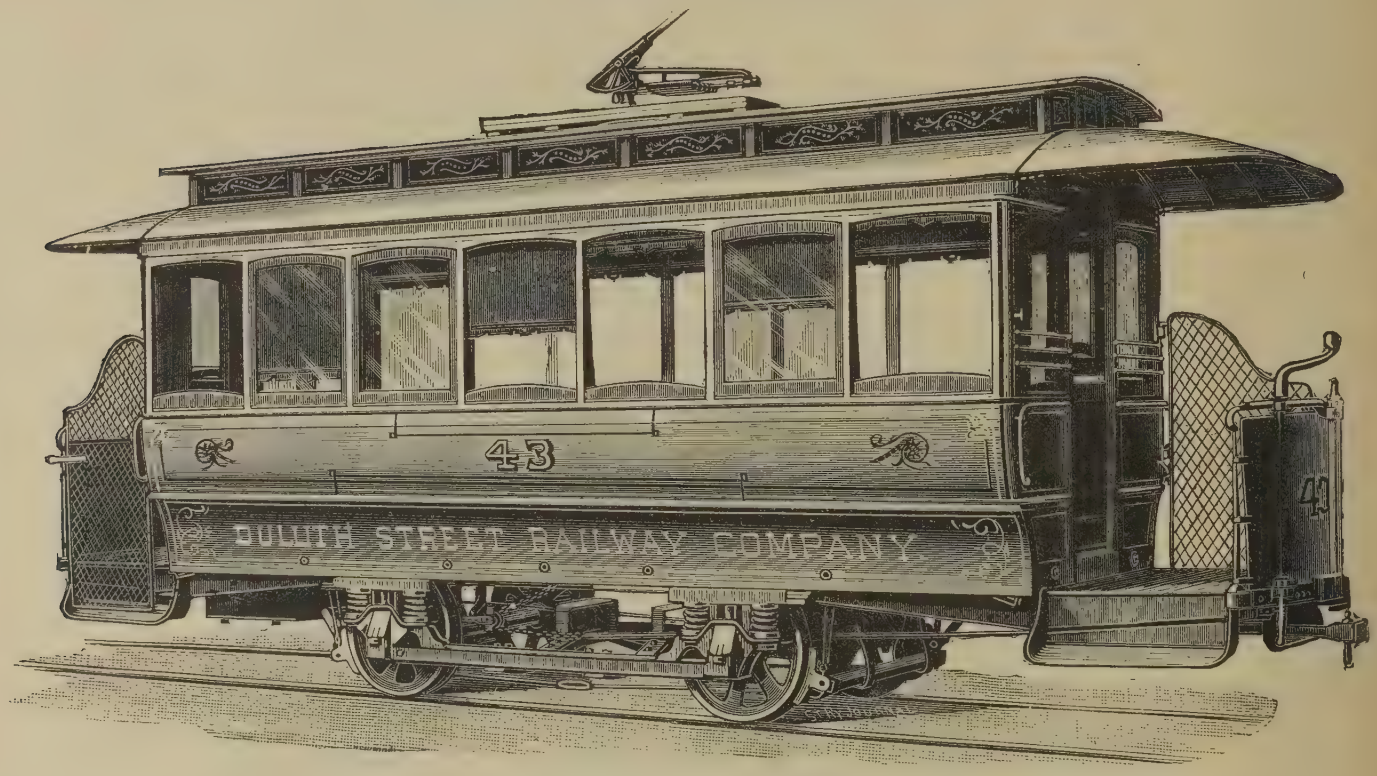

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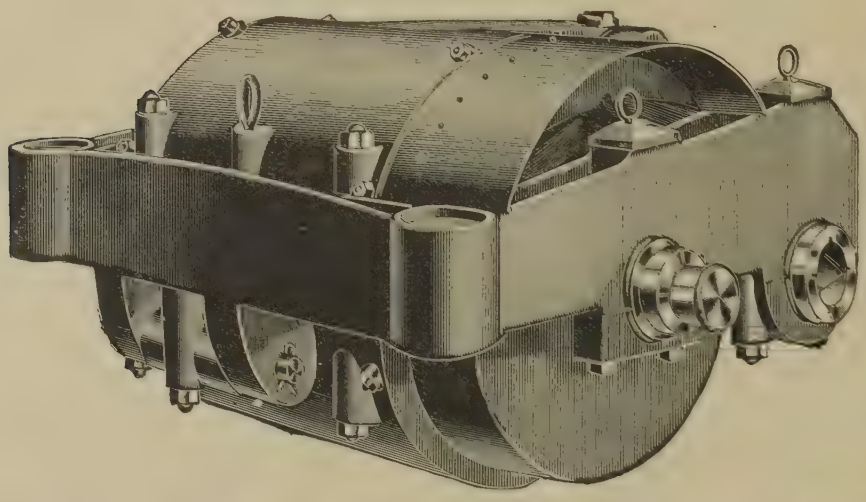

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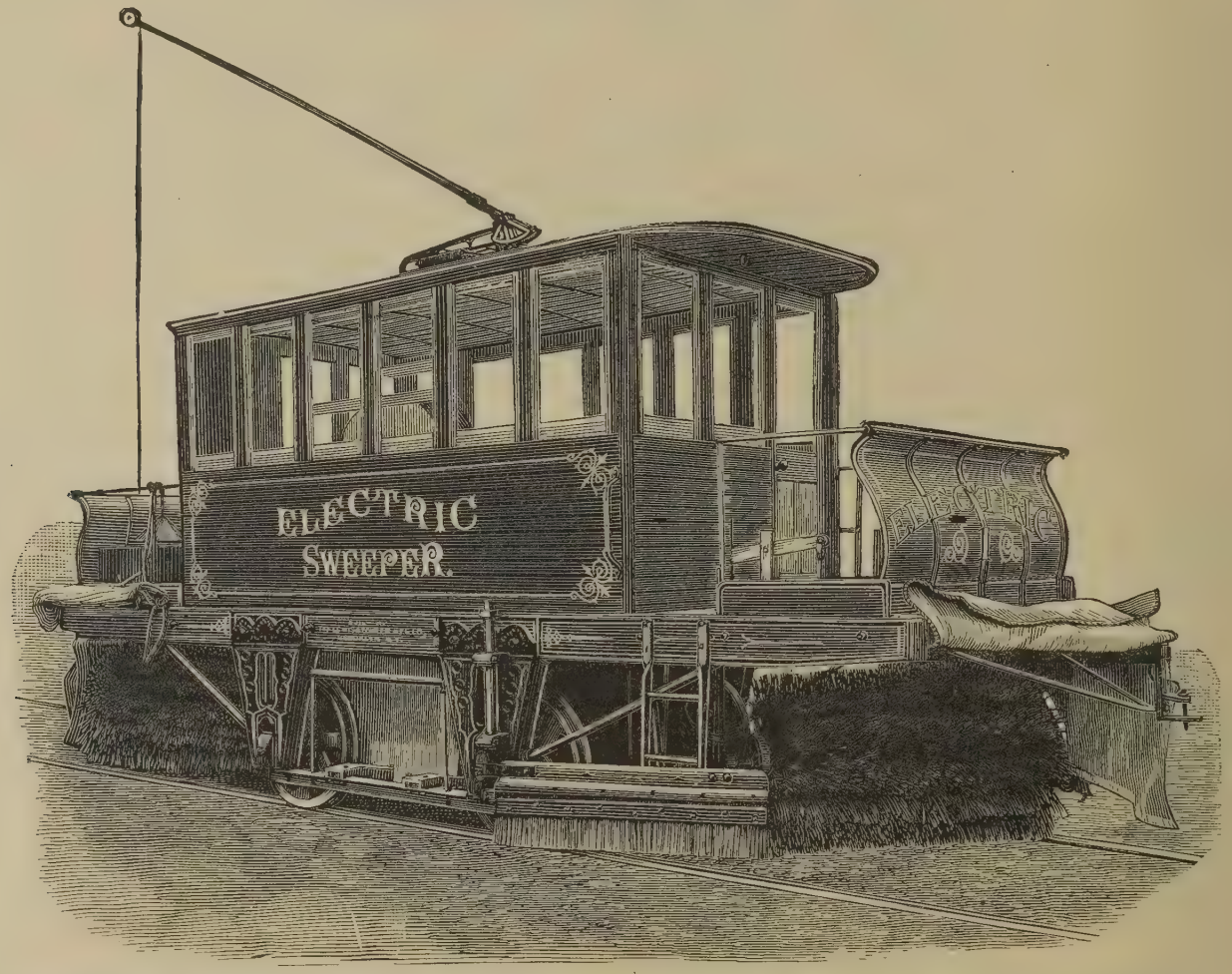

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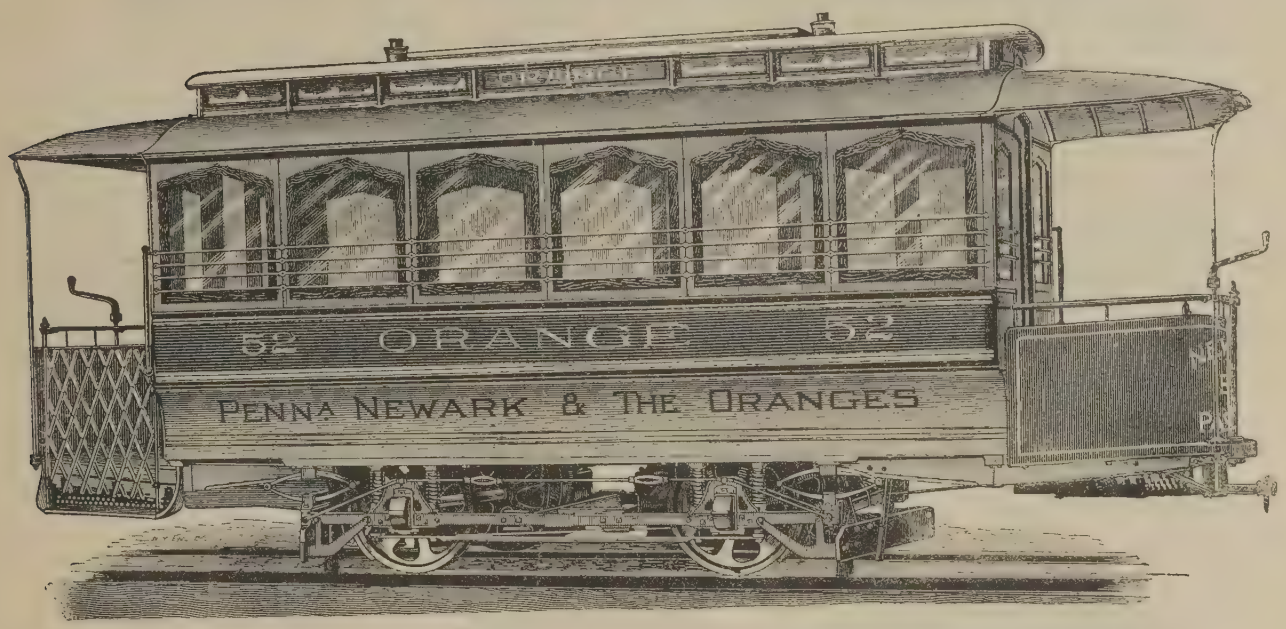

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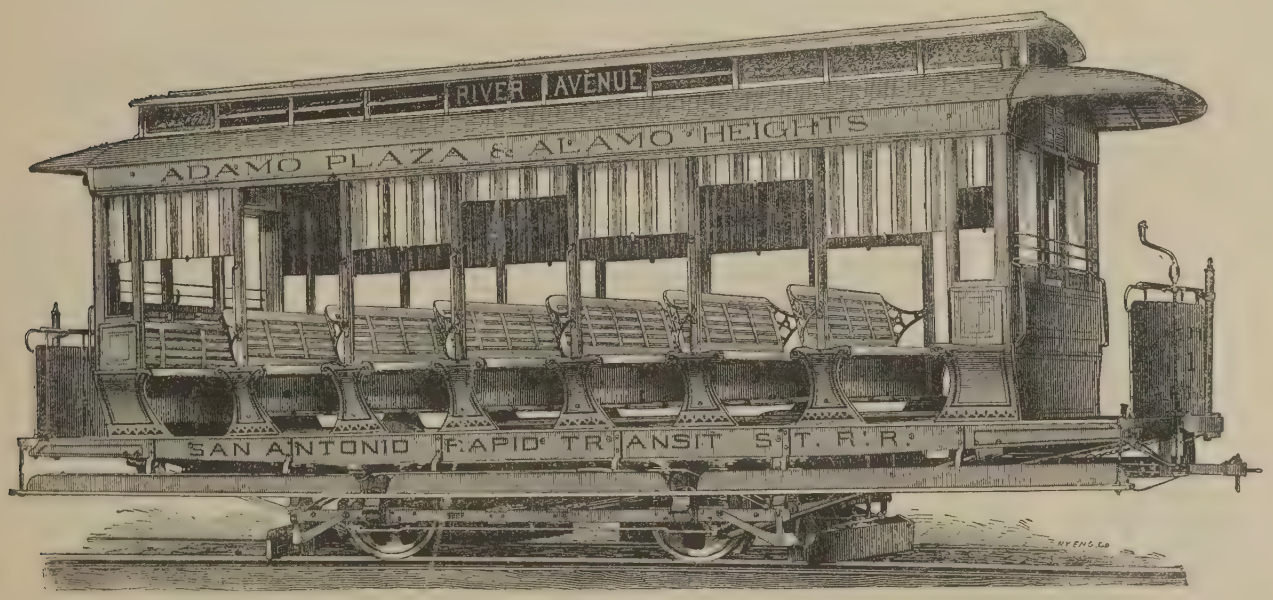

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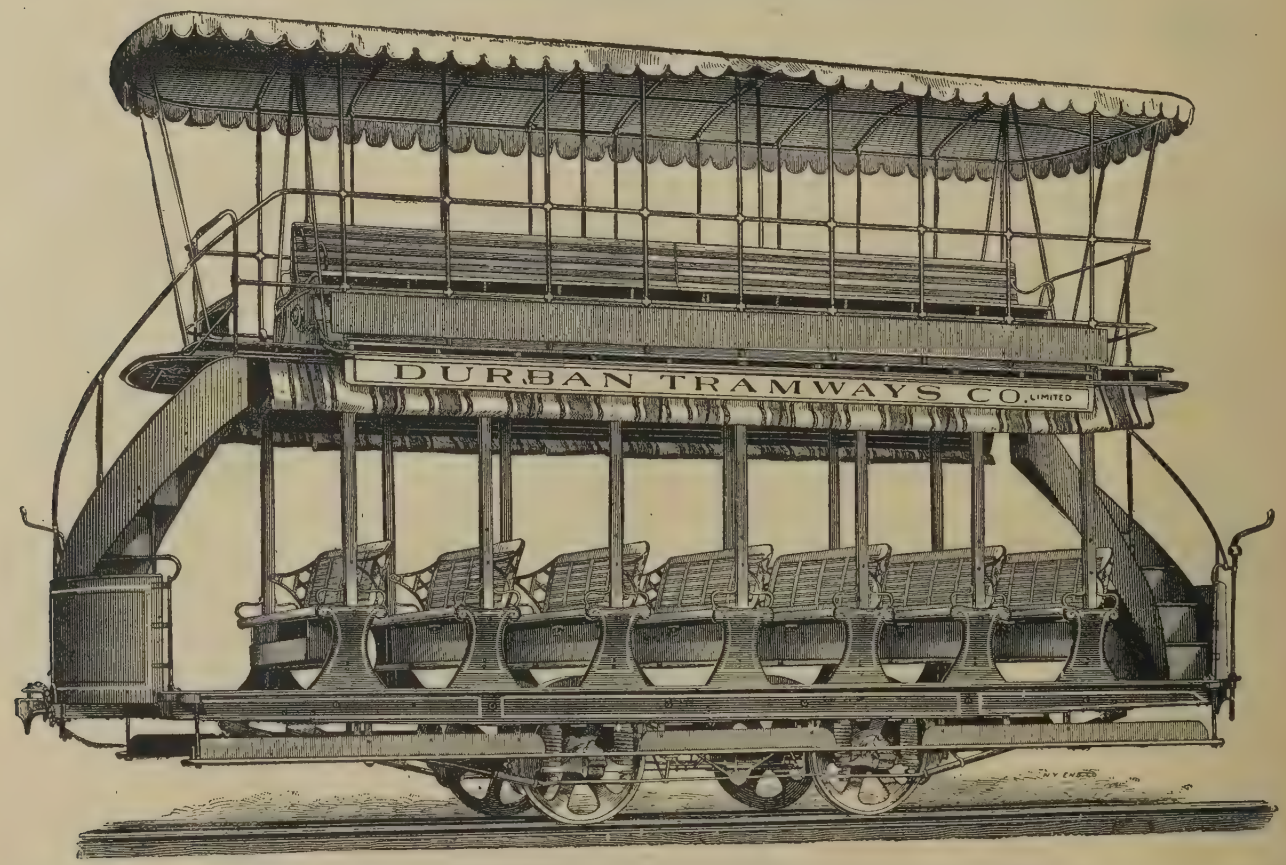

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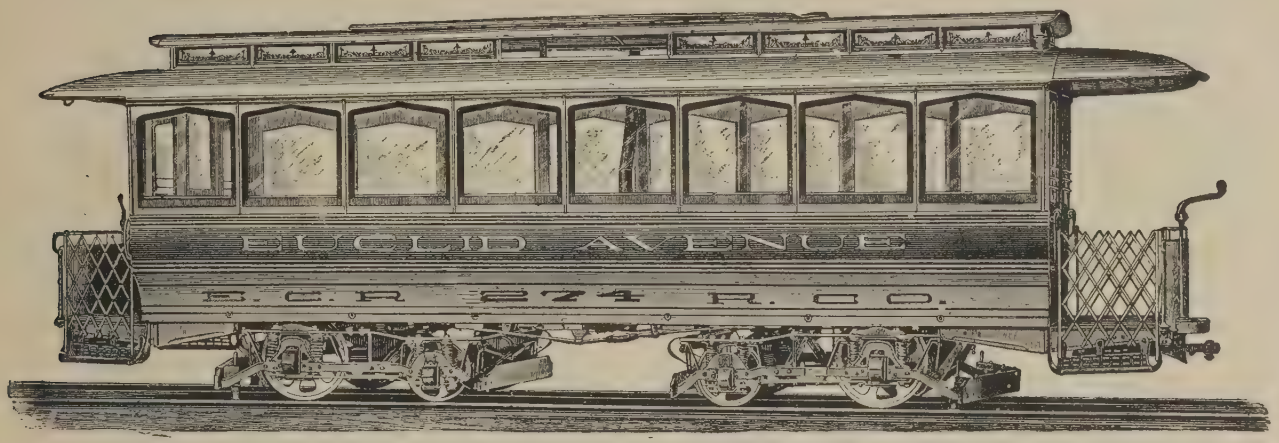
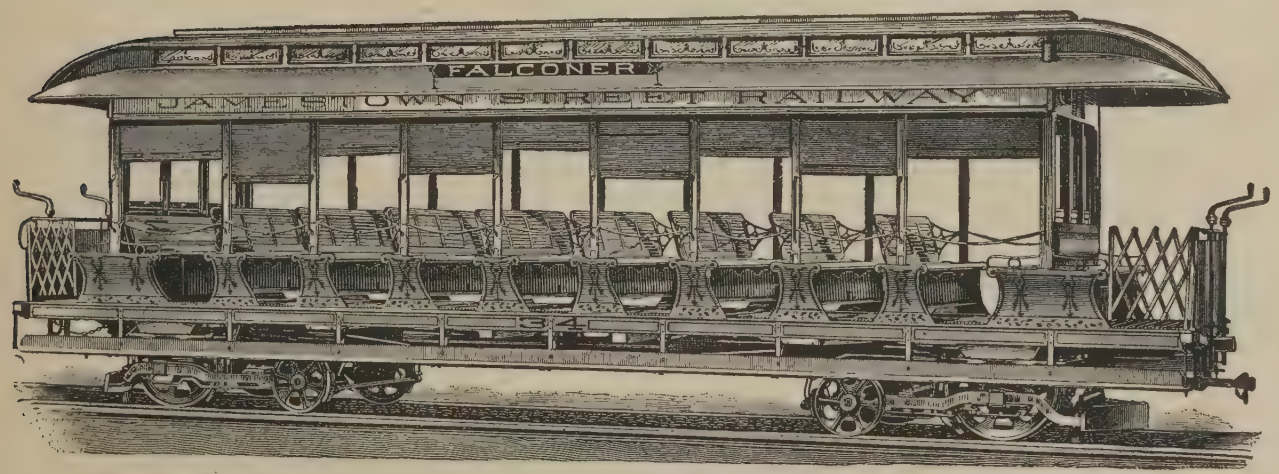


STANDARD 25 FT. CLOSED ELECTRIC MOTOR CAR ON EUREKA MAXIMUM-TRACTION PIVOTAL TRUCKS.



TWELVE SEAT OPEN ELECTRIC MOTOR CAR ON EUREKA MAXIMUM-TRACTION PIVOTAL TRUCKS.

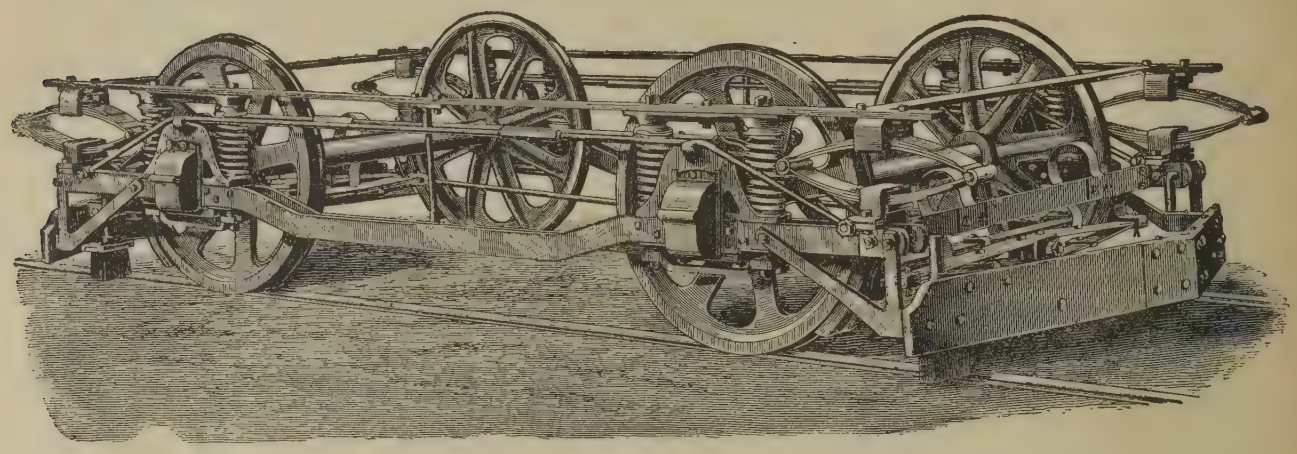
WESTERN OFFICE:

PHENIX BUILDING, CHICAGO.

J. G. BRILL COMPANY,

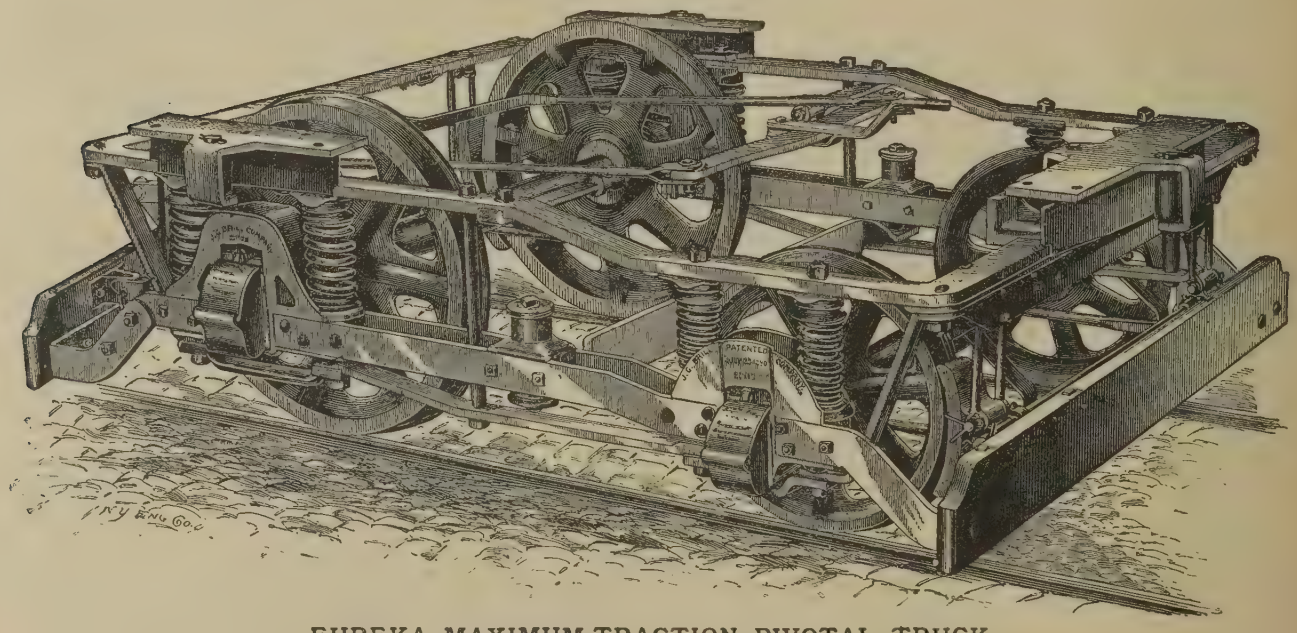
PHILADELPHIA,

BUILDERS OF RAILWAY AND TRAMWAY CARS.



BRILL'S NO. 13 PATENTED INDEPENDENT RIGID MOTOR TRUCK.

ADOPTED AS STANDARD BY THE LEADING ELECTRIC RAILWAYS IN AMERICA.



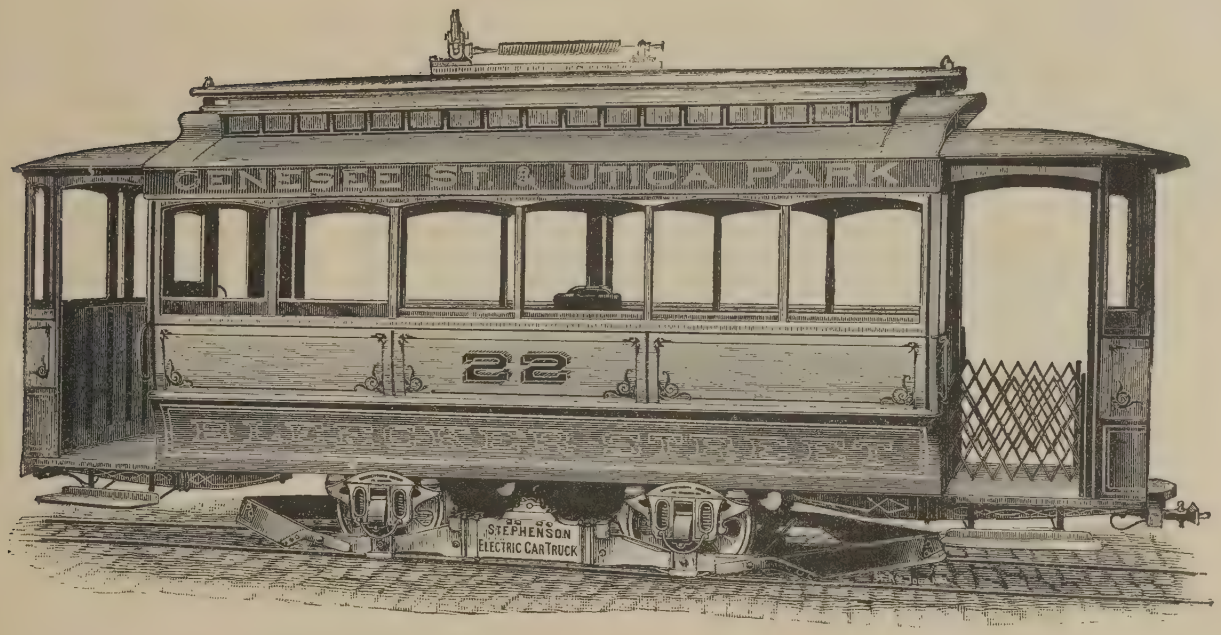
EUREKA MAXIMUM-TRACTION PIVOTAL TRUCK.

Increased Traction. Easy Running. Low Car Body.

SPECIALLY CONSTRUCTED FOR ACCESSIBILITY OF MOTORS.

JOHN STEPHENSON COMPANY, LIMITED,

NEW YORK.



STREET CARS.

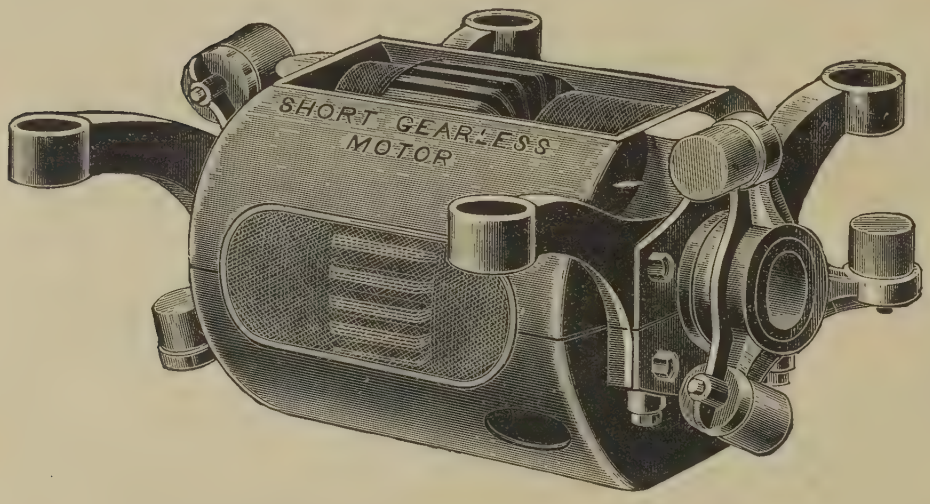
ELECTRIC.

CABLE. HORSE.

THE

Short Electric Railway Co.

SHORT GEARLESS MOTORS.



FLEXIBLE SUSPENSION AROUND CAR AXLES.

THREE (3) WEARING PARTS.

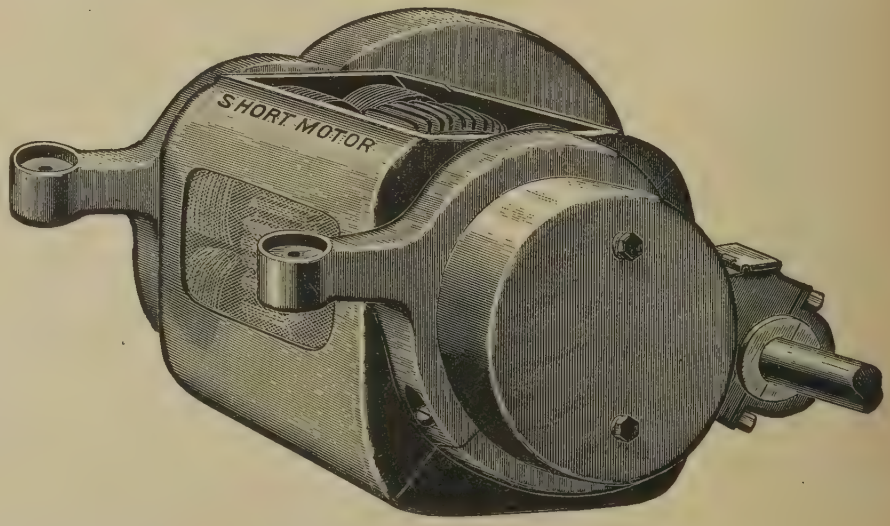
VERY HIGH EFFICIENCY.

EXPENSE OF REPAIRS NOMINAL.

SINGLE REDUCTION MOTORS.

BY ACTUAL TEST IN DAILY SERVICE SHOW A HIGHER EFFICIENCY THAN ANY OTHER GEARED MOTORS MANUFACTURED TO-DAY.

EASILY INSPECTED.
EASILY REPAIRED.



——SEND FOR CATALOGUES.——

THE SHORT ELECTRIC RAILWAY CO.

CLEVELAND, OHIO.

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